SOUTH DAKOTA SCHOOL OF MINES

Bulletin No. 9.

DEPARTMENT OF GEOLOGY.

THE BADLAND FORMATIONS

OF THE

BLACK HILLS REGION

BY

CLEOPHAS C. O'HARRA

Rapid City, South Dakota,
November, 1910.

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THE DAILY JOURNAL
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Letter of Transmittal.

South Dakota School of Mines,
Rapid City, June 15, 1910.

SIR: I have the honor to transmit herewith the manuscript of "The Badland Formations of the Black Hills Region", by Cleophas C. O'Harra, Ph. D., Professor of Geology, at the School of Mines.

I submit the paper with the recommendation that it be published as Bulletin No. 9 of the School of Mines.

Respectfully,

CHARLES H. FULTON, President.

HON. A. J. NORBY,
Vice President, Regents of Education.

PREFATORY NOTE.

This paper is written to supply the need, so often expressed, of a concise summary description of the badland formations of the Black Hills region. It is intended primarily for those who may not have had training in geologic and paleontologic study, but who are interested in gaining an intelligent idea as to the meaning of the Badlands. In so far as it is reasonably possible, therefore, the paper is brief, general, and of a non-technical character.

A vast amount of work and a great sum of money have been expended during the last sixty years and more in the study of our badland deposits but the results of all this have been published in abstruse scientific papers distributed for the most part beyond the reach of any but the specialist having access to well-equipped libraries. In a few large museums, reference to which is made in the following pages, a generous display of the carefully restored fossil remains has served in a measure to relieve the condition, but even this has its limitations particularly as regards immediate usefulness to those who have little or no opportunity to visit the cities in which the museums are situated.

I have made effort not only to present in readable form the most important and most interesting facts concerning the badland deposits but also to provide, for those who may desire it, a convenient help to further study. Readers who may wish to enquire more fully into the literature will find in the bibliography a list of the more important publications. I have also given a full list to date of all well-defined species of the fossil animals that have been identified, together with reference to the publication containing their earliest description.

It is perhaps unnecessary to say that in writing this paper I have drawn liberally from the works of many men of science, who have spent arduous years that they might have a part in unravelling the marvellous story of these strange lands. In

collecting and summarizing this information for the layman I have endeavored in every way to see that the original investigators receive full credit for whatever of their results I may have used. I regret the impossibility of naming the many artists, engravers, preparators, field assistants and others who from the earliest days have conscientiously and in a painstaking way contributed to the grand total of accomplishment. Their work has been essential and in the original literature has in general received full recognition. A reasonable regard has been entertained for the relative importance of the varied kinds of investigation. Necessarily countless details of description have been omitted, but care has been taken throughout to see that brevity of description has not necessitated sacrifice of accuracy.

My gratitude extends in many directions for literature consulted and for material used. I am indebted particularly to the Foote Mineral Company of Philadelphia for permission to reproduce from their Catalogue of Minerals Plate No. 15, and to Mr. Henry R. Knipe of Tunbridge Wells for permission to reproduce Plates Nos. 24, 30, 39, originally drawn by Mr. T. Smit for the volume "Nebula to Man" recently published by Messrs. J. M. Dent & Company of London. In an especial way I am indebted to Professor Henry F. Osborn and the American Museum of Natural History of New York, through whose generosity I have been permitted to use the copyrighted photographic prints reproduced in Plates Nos. 27, 29, 32, 40, 42, 47 and Figure 1 of No. 33, the originals of which, from drawings and paintings made by Mr. Charles R. Knight under the direction of Professor Osborn, are in the American Museum of Natural History. Lastly I wish to record my appreciation of favors rendered by President Charles H. Fulton and the Regents of Education. It is due them to state that their hearty cooperation has greatly added to whatever value the paper may possess and has augmented in no little degree my interest in its preparation.

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Photograph by O'Harra, 1909.

The Gateway, School of Mines Canyon at northwest base of Sheep Mountain, Pennington County, South Dakota.

THE BADLAND FORMATIONS
OF THE
BLACK HILLS REGION

BY CLEOPHAS C. O'HARRA

INTRODUCTORY

The badland formations of the Black Hills region have for many years been the source of the most varied interest. They are made up of rocks showing generally rapid disintegration and owe their name to the peculiar nature of the type locality of their exposure.

The term "badland" does not lend itself readily to accurate definition but custom and convenience permits its use in harmony with the name Badlands as understood by the early French-Canadian hunters and trappers who, imitating the poetic *"Ma-koo-si-tcha"* of the Dakota tongue applied the name *"Mauvaises Terres"* to the area southeast of the Black Hills lying along the White and Cheyenne rivers. The words were meant to signify a country difficult to travel through chiefly because of the rugged surface and general lack of good water. For many purposes surface features have been the only criteria recognized in defining the term but among scientific men "badland formation" especially as used with reference to the North Central Great Plains has approached specific importance and refers, unless otherwise stated, to deposits of Tertiary age. This does not imply that all Tertiary rocks and only Tertiary rocks come rigidly under the badland class, but this is so generally true in the Black Hills region that in this paper I consider the terms synonymous, preferring to use the less technical term in deference to the convenience of the non-technical reader. Deposits other than those of Oligocene Tertiary and Miocene Tertiary are not described. It is possible that Fort Union beds may be represented within the area covered by the northern part of the map since recent study seems to have shown their presence in large areas in southwestern North Dakota where they make

up a considerable portion of the badlands of that state. In view of the fact, however, that these rocks have not been differentiated in the nearer areas and especially because here their badland topography is generally of little significance no further reference is given them. Pliocene deposits, known to occur near the southern border of the area mapped, are likewise omitted. These deposits have afforded interesting fossils but they have received only preliminary attention and their areal distribution has not been determined. Still later materials, namely, Pleistocene and Recent are rather widely scattered in narrow belts or little disconnected patches over the entire area. As in the case of the others just mentioned, these are not described.

Badland Tertiary areas are represented in various parts of the world but nowhere are they so well developed as in the United States. They are found particularly in South Dakota, Nebraska, Colorado, Wyoming, North Dakota, Montana, Oregon, Utah and New Mexico. Of all these deposits those in the Black Hills region, indicated on the accompanying geological map, are vastly superior in complexity and extent so far as concerns typical badland topography and are unequalled the world over in their astounding wealth of vertebrate remains.

The badland areas of the Black Hills region constitute a much misunderstood portion of American territory. The term "badland" is in itself detractive although apt enough in early frontier days when hardships of travel were rigorous enough even under the best of circumstances. Much the greater portion of the area within the badlands as commonly understood is level and fertile and covered with abundant rich grasses and recent occupation by thousands of settlers has brought out the fact that over large tracts, especially on the higher tables, good refreshing water may be obtained by sinking shallow wells in the thick soil and gravel mantle that occurs rather widespread over the surface. The country has in years gone by been of much value as an open range for the grazing of cattle and horses. Since the building of the railroads the land has largely passed from the government to private ownership and farming on rather an extensive scale has been carried on. Farming, especially in the Big Badlands, has not yet passed the initial stage, but abundant rains during the time of occupancy thus far has given promise of good success. Within little more than a stones throw from where the early explorers spoke of the region as an inferno for heat and drought men have built homes for themselves and their families and have been raising good crops of staple grains

while prices are paid for land undreamed of before the coming of the railroads and their attendant comforts. Plate 23 shows one of the old time ranches near Imlay, including its well kept vegetable garden within the very heart of the Big Badlands and Figure 1 shows the proportion of occupied and unoccupied land

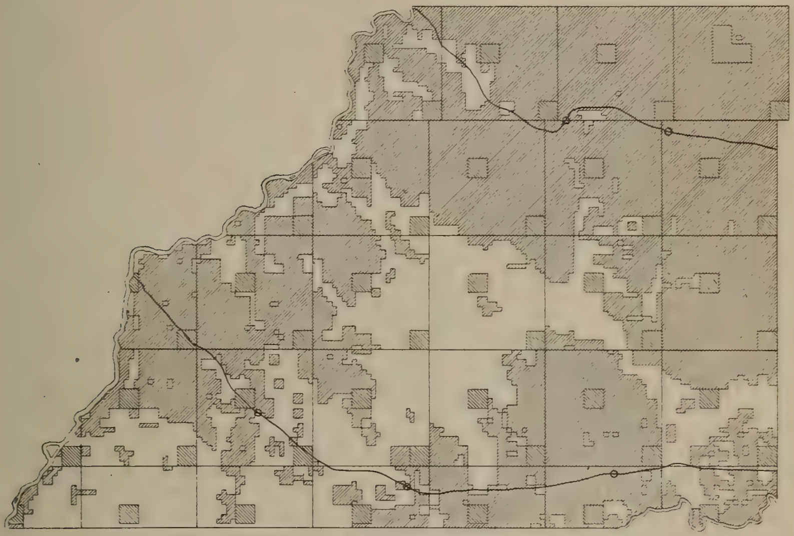

Figure 1—Southern part of eastern Pennington County. Ruled portion shows land patented or filed upon, including school sections.

in the southern part of eastern Pennington County, within and immediately adjacent to the most typical of all the badlands. Approximately three-fourths of this occupied land has been patented and is now under private ownership.

But it is to the badland formations as an educational asset that I would call particular attention. Nowhere in the world can the influences of erosion be more advantageously studied or more certainly or quickly understood. Nowhere does the progress of mammalian life reveal itself with greater impressiveness or clearness. Nowhere do long-ago days connect themselves more intimately with the present nor leave more helpful answers to our wondering questions as to the nature and import of the earth's later development.

Knowing the help of even a hasty examination of this wonderful work of nature I have during the past twelve years taken most of my students of geology at the State School of Mines

through the marvelous network of rounded hillocks, wedge slopes, grassy flats and sheer declivities about Sheep Mountain and the Great Wall, the highest and ruggedest portions of all the badlands. The Great Wall viewed from White River valley, presents a particularly rugged aspect and, like the great wall that it is, stretches for many miles in a nearly east-west direction, disclosing for much of the distance a continuous skyline series of towers, pinnacles and precipitous gulches. Much of the view from the top of Sheep Mountain, which projects five hundred or six hundred feet above the lower valleys, is hopelessly indescribable. Far away cattle may be seen feeding on levels of green and here and there distant dots in ruffled squares indicate the new abodes of sturdy homesteaders. Immediately about all is still. The sharp eye may possibly detect a remnant bunch of mountain sheep, once numerous in this locality, but quickly and quietly they steal to cover among the intricate recesses of the crumbling precipices. The song birds seem to respect the solitude. Only an occasional eagle screams out a word of curiosity or defiance as he sails majestically across the maze of projecting points and bottomless pits. Magnificent ruins of a great silent city painted in delicate shades of cream and pink and buff and green. Domes towers, minarets, and spires decorate gorgeous cathedrals and palaces and present dimensions little dreamed of by the architects of the ancients. At first there may come a feeling of the incongruous or grotesque but studying more closely the meaning of every feature the spirit of this marvelous handiwork of the Great Creator develops and vistas of beauty appear.

Here on Sheep Mountain or on the higher points of the Great Wall the contemplative mind weaves its way into the long ago. There first come visions of Cretaceous time. A vast salt sea stretches as a broad band from the Gulf of Mexico to the Arctic regions and slowly deposits sediments that are destined to form the great western plains of the continent. Strange reptiles sport along the shores of this sea and myriads of beautiful shell-fish live and die in its mud-laden rush-fringed bays. Changes recur, the salt becomes less pronounced, the sea grows less deep, brackish conditions prevail but the animals and plants with many alterations and advancements live on. Deep rumblings in the northern Black Hills, and in the Rocky Mountains, with accompanying porphyry intrusions, portend widespread changes, the shallowing sea slips away and fresh water marshlands and deltas prevail. The Tertiary comes and with the

close of its first division the badland formations as represented in the Black Hills region, begin to be deposited. Barriers somewhere are let down and a great horde of new animals of higher type appears. Here in the foreground gently flowing streams push their muddy way through reedy marshlands and vigorous forests and furnish a lazy playground for countless turtles and occasional crocodiles. In favored recesses groups of rhinoceroses may be seen, some heavy of bulk and water loving, others graceful and preferring dry land. Little fleet-footed ancestral horses with names as long as their legs nibble the grass on the hillsides or by means of their spreading three-toed feet trot unhindered across the muddy flats, the nearest restraining rider being more than a million years away. Here and there we see a group of predaceous dogs and not infrequently do we get a glimpse of a ferocious tiger-like cat. On the higher ridges, even far within the hills and mountains six horned herbivores reveal their inquisitive pose and perhaps anon, like the antelope, show their puffs of white as they scamper from the nearing presence of some stealthy foe. But the "reigning plutocrat" is the Titanothere. In great numbers we see his majestic form as he moves among his kin and crops at his leisure the coarse grasses of the lowlands. Here and there are beavers and gophers and squirrels busy with their toil and their play, and hedgehogs and moles and swine and deer and tapirs and camels, and many other creatures too strange to mention without definition. Because the badlands as we now know them were so long little frequented by man except in favored places do not think the country was then a barren waste or a place of solitude. To all these animals it was home. To them the sun shone, the showers came, the birds sang, the flowers bloomed, and stately trees gave convenient shade to the rollicking young of many a creature.

But "everlasting hills" have their day and rivers do not flow on forever. These animals, under a Guiding Providence, having inherited the more essential characters of their ancestors, and developing new traits as a result of their environment, in turn transmitted to later individuals the features best fitted to serve their purpose in the winning of life's great race. One by one, group by group, they died, the bodies of most of them quickly feeding the surrounding elements but a chosen few, tucked away by the kindly hand of nature, serving as unique monuments of the dawning time of the great mamma-

lian races, are now being revealed as gently by nature again in these the days of man.

HISTORY OF EXPLORATION

Our first knowledge of the badland formations of the Black Hills region worthy of record dates from 1847. Early in this year Dr. Hiram A. Prout of St. Louis described in the American Journal of Science a fragment of the lower jaw of a Titanothere, he calling it a Paleotherium (see Figure 2).* A

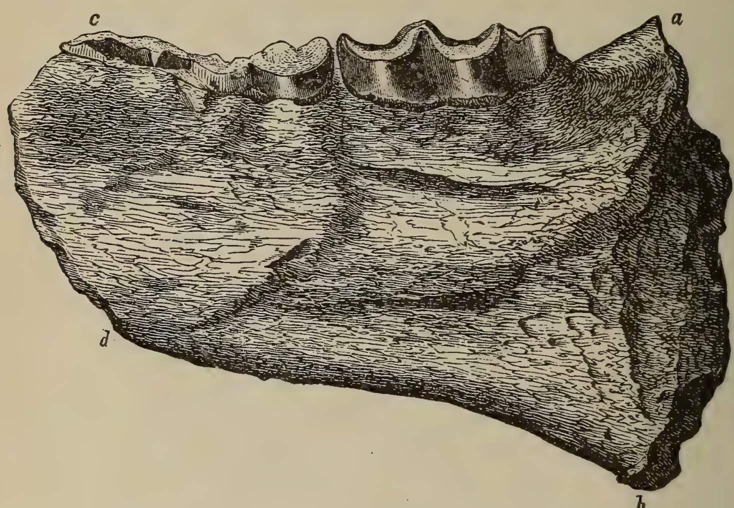

Figure 2—Fragment of the lower jaw of a Titanothere, the first fossil discovered in the Big Badlands. Described by Dr. H. A. Prout, of St. Louis, 1846-7.

few months later Dr. Joseph Leidy described in the Proceedings of the Academy of Natural Sciences of Philadelphia a fairly well preserved head of what he termed a Poebrotherium (see Figure 3). The name implies belief in the ruminating nature of the animal and later investigation, strange as it may seem, showed it to be an ancestral camel. The two specimens referred to were obtained from representatives of the American Fur Company and were secured near the heart of the Big Badlands.

The descriptions of these specimens aroused much interest

*A slightly earlier reference to this specimen may be found in the same journal for 1846, under "Miscellaneous Intelligence," but this is merely a brief preliminary note and is unsigned.

among men of science and in 1849, Dr. John Evans in the employ of the government under the direction of David Dale Owen of the Owen Geological Survey visited the region for the pur-

Figure 3—Head of an ancestral camel (Poebrotherium), the earliest badland fossil described by Dr. Joseph Leidy, of Philadelphia. Published 1847.

pose of studying its peculiar features and of collecting additional fossils for the purpose of determining the age of the strata. This visit was of the greatest importance and the results were early published in a most careful scientific manner. The report, chiefly the work of Dr. Leidy, who described the fossils and Mr. Evans who through Mr. Owen reported upon the geography and geology, gave to the world the first authentic description of the nature of the badland country.

Interest in the region heightened and other expeditions were sent out. Most of these during the earlier years confined their attention chiefly to the Big Badlands, but one of the explorers, Prof. F. V. Hayden, who later became head of the Hayden Survey, officially known as the U. S. Geological Survey of the Territories, found opportunity at various times to study the Black Hills highland and thus he was early able to make known the close geologic and physiographic relationship of the main uplift to the surrounding country. Mr. Thaddeus A. Culbertson under the auspices of the Smithsonian Institution came in 1850. In 1853 there were two expeditions, one by F. V. Hayden and F. B. Meek by direction of Prof. James Hall, of New York, and one by John Evans and B. F. Shumard, who were at the time connected with the Stevens expedition of the Pacific Railroad Survey. Prof. Hayden studied the region again in

1855 and 1857 while in connection with the Lieutenant Warren explorations of Dakota and Nebraska. He made a final visit to the region in 1866 under the direction of the Philadelphia Academy of Sciences. These parties collected vertebrate fossils of the greatest scientific value and Dr. Leidy, whom I have already mentioned, being recognized as best fitted of all men in America to determine the nature of such fossils, was called upon to write their description. Important papers rapidly issued from his pen and each new description served to point out the need of further exploration. In 1869 he published in the Journal of the Academy of Natural Sciences of Philadelphia his monumental work, "The Extinct Mammalian Fauna of Dakota and Nebraska." In this large volume he brought together the accumulated information of more than twenty years and fittingly closed what serves as the first of three fairly defined epochs in the development of knowledge of our badland formations.

The year 1870 marks the beginning of the second epoch. During this year the First Yale Scientific Expedition visited the region under the direction of Prof. O. C. Marsh. Prof. Marsh had made a brief visit of inspection two years befre this, but in 1870 he began the collecting of fossils. Prof. Marsh, not satisfied with the crude methods of collecting with which the earliest investigators had to content themselves, undertook extensive quarrying for the fossils, and developed also more refined methods of utilizing detached and broken pieces. In this way a number of well-preserved, complete, or nearly complete, skeletons were obtained where before the material was weathered and fragmentary. Complete restorations of skeletons disclose structural features much more readily than detached bones and imperfect fragments, and Prof. Marsh first extensively developed this feature for the fossil vertebrates of the South Dakota and other western badlands. He was thus able to emphasize more easily the nature of these animals and to point out more clearly their profoundly significant relation to present-day life. Prof. Marsh continued field work for many years, the collecting being done sometimes by expeditions directly from Yale, sometimes by collectors hired for the purpose. Following the first Yale expedition of 1870, other Yale expeditions were in the region in 1871, 1873, 1874, and hired collectors in 1886, '87, '88, '89, '90, '94, '95, '97, '98.

In this connection it may be stated that during the years 1886-'90, much of the field work directed by Marsh was done under the auspices of the U. S. Geological Survey, the materials

collected being later transferred to the U. S. National Museum. Much of this collecting, particularly during the years 1886, '87, '88, was in immediate charge of Mr. J. B. Hatcher, one of the most original and successful collectors that has ever worked in the Badlands.

The Newton-Jenney survey of the Black Hills, under direction of the Department of the Interior, was made in 1875. The attention of this survey was directed particularly to the pre-Tertiary rocks. Only brief study was given the Tertiary flanking the nearer foothills and practically none at all to the deposits farther away.

The second epoch in the investigation of the badland formations corresponds fairly closely, but not precisely, with the Yale and U. S. Geological Survey field work. It may perhaps be best considered as closing and the third epoch as beginning with the first expedition under the direction of the American Museum of Natural History in 1892.

Important investigations begun by Princeton University during the second epoch continued into the third. Princeton was first represented by an expedition under direction of Prof. W. B. Scott in 1882. Another expedition directed by Prof. Scott, came in 1890. A third came in 1893, directed as before by Prof. Scott, with whom was associated Mr. J. B. Hatcher. A fourth party came in 1894, this time under the full direction of Mr. Hatcher. The results of these expeditions were of very great importance. The abundant fossil remains collected enabled Prof. Scott to describe in a most complete manner a number of the more noted extinct animals and to indicate with more certainty their proper classification and relationship.

The American Museum of Natural History entering the field in 1892, was favored from the very first by important discoveries. Since the first expedition, several parties have represented this institution in its field investigations. Backed by abundant means and made up of capable investigators, they have been able to carry home a large amount of extraordinarily valuable material. This has given opportunity to establish more accurately the details of stratigraphy and correlation and to indicate with greater certainty the characteristics and habits of the various animals while in the living state. The years in which parties have been in the field, either in South Dakota or northwestern Nebraska are, 1892, '93, '94, '97, '03, '06, '08. Under the direction of Prof. H. F. Osborn, Curator of the Department of Vertebrate Paleontology, earlier a co-worker with Prof. Scott

in the Princeton investigations, many of the best preserved skeletons complete in practically every detail and mounted with the greatest skill, have been clothed with flesh, life and activity. Reproductions of a number of these, reference to which is made on other pages, are given in this bulletin.

The University of Nebraska sent expeditions under direction of Prof. Barbour in 1892, '94, '95, and '97. Much of their collecting was done in northwestern Nebraska, but a considerable part of it in South Dakota and Wyoming. Prof. Todd, cf the University of South Dakota, spent a brief time in the field in 1894. He made a second and more lengthy visit, accompanied by several students, in 1896.

New impetus was given the work, particularly among the Miocene formations of northwestern Nebraska and eastern Wyoming, by the inauguration in 1902 of explorations by the Carnegie Museum of Pittsburg. This has continued to the present time. Mr. Hatcher directed much of the earlier work, while later, Mr. O. A. Peterson has had charge of it. This museum, as in the case of the American Museum, has been particularly successful, and many new and strange species have been discovered and described. A discovery of special note is that of the rich and important bone deposits near Agate Springs, found in 1904.

Two other institutions have each sent expeditions to the Badlands, namely, Amherst College, under Prof. Loomis in 1903, and Field Museum, under Curator O. C. Farrington, in 1904. Amherst was also represented in northwestern Nebraska in 1907.

In addition to the expeditions equipped by the several institutions, various private collectors have obtained large quantities of valuable material and these specimens, either directly or through dealers, have found their way into the best museums, both at home and abroad. Now that access to every part of the Badlands is readily gained, investigators are constantly visiting the region and activity in the development of knowledge cocerning these wonderful deposits has perhaps never been more vigorous nor better planned than it is at the present time. Each succeeding year enhances the quality and importance of the investigation and doubtless this will continue true for many years to come.

GEOGRAPHICAL DISTRIBUTION

The badland formations of the Black Hills region constitute but a remnant of a once vast earthblanket stretching for

A PRELIMINARY MAP OF THE BADLAND FORMATIONS OF THE BLACK HILLS REGION

Chiefly from the Survey of Darton (1905) as Modified by Matthew and Thomson (1906-07)

Mostly Lower Miocene. Known to contain some Upper Miocene, Pliocene, and Pleistocene. Possibly includes also some Middle Miocene.

Middle and Upper Oligocene. Brule Formation (Oreodon and Protoceras Beds).

Non-differentiated Oligocene (Chiefly Chadron Formation.)

Lower Oligocene. Chadron Formation (Titanotherium Beds.)

hundreds of miles north and south along the eastern slopes of the Rocky Mountain front. Their original plainsward extension is not always well defined but in South Dakota they reached eastward to near the James river valley. Of the Black Hills proper only the highest portions seem to have remained uncovered. Apparently from these restricted areas as well as from the far greater Rocky Mountain region detrital materials had opportunity throughout the period to add their volume to the deposits of the bordering lowlands. Later this vast series of sediments was elevated and gradually trenched by innumerable streams and most of the material has been washed away. Along the Little Missouri river only a few isolated buttes and tables such as Castle Rock, Haystack Butte, Deers Ears, Slim Buttes, Short Pine Hills, Long Pine Hills, and Cave Hills, made up partially or wholly of badland materials, remain to indicate the enormous erosion that has taken place.

The most important and best connected tracts are southeast, south, and southwest of the Black Hills but areas of no mean significance occur in many places within the Hills themselves. In the Northern Hills there are many isolated areas mostly small and irregular and generally lying upon or near the highest shoulders of the more important mountain masses. The most extensive are those of the Bear Lodge range where north and west of Warren Peaks the deposits cap several of the ridges and gently sloping tables to a height of nearly 6,000 feet. The highest of these are more than 2,500 feet higher than the highest points in the Badlands between Cheyenne river and White river. In addition to the Bear Lodge tracts three small areas are found near Missouri Buttes, a half dozen or more between Nigger Hill and Beulah, one at Maitland, another between Maitland and Spearfish, and two at Lead.

Farther south the Black Hills are more intimately connected with the formations. Within the higher areas here the deposits are not abundant, being confined chiefly to small areas near Argyle, Minnekahta, and Custer, but between Rapid City and Buffalo Gap they cover large portions of the foothills and in places extend outward almost without break to the great area beyond the Cheyenne river. In addition to this the high tables in the Big Badlands and the infacing escarpment of Pine Ridge proclaim clearly enough their former Black Hills-ward extension.

The locality of chiefest interest is near the southeastern border of the Black Hills between the White and Cheyenne rivers. This is known as the Big Badlands and is the area

showing the greatest tropographic complexity. It is continuous with the larger and greatly important area south of White river. This latter extends eastward, beyond the area of the map into Rosebud Indian reservation and southwestward and westward alongside the upper White river forming the high Pine Ridge escarpment which extends through northwestern Nebraska into Wyoming.

The typical badland topography is of little importance south of Pine Ridge within the area covered by this paper. However, since the geology and paleontology there is closely related to the geology and paleontology of the adjoining areas in South Dakota and since the southern slope of Pine Ridge marks the approximate southern structural limit of the Black Hills uplift the map is made to include the area southward to and a little beyond the Niobrara river.

CLASSIFICATION AND CORRELATION

The history of the earth since the advent of life on its surface is commonly divided into certain time-divisions called eras. Beginning with the oldest, these are the Archeozoic, the Proterozoic, the Paleozoic, the Mesozoic, and the Cenozoic.* Each of these eras is divided into shorter time-divisions known as periods, varying somewhat among authors. For example the Paleozoic may be divided into the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pensylvanian, and Permian periods; the Mesozoic into Triassic, Jurassic and Cretaceous; the Cenozoic into the Tertiary and Quaternary. The periods may in turn be divided into epochs, as for example, the Tertiary into the Eocene, the Oligocene, the Miocene, and the Pliocene epochs; the Quaternary into the Pleistocene or Glacial epoch, and the Recent or Human epoch. The rocks laid down during the various epochs or periods are spoken of as being grouped into formations (not to be confused with the ill-defined expression often used for any natural oddity) the name of each formation being usually derived from some town, stream, tribe of people, or other feature of local interest where the formation was first carefully studied and described. The following section in order of deposition, the oldest being at the bottom, shows the various formations for the Black Hills region.

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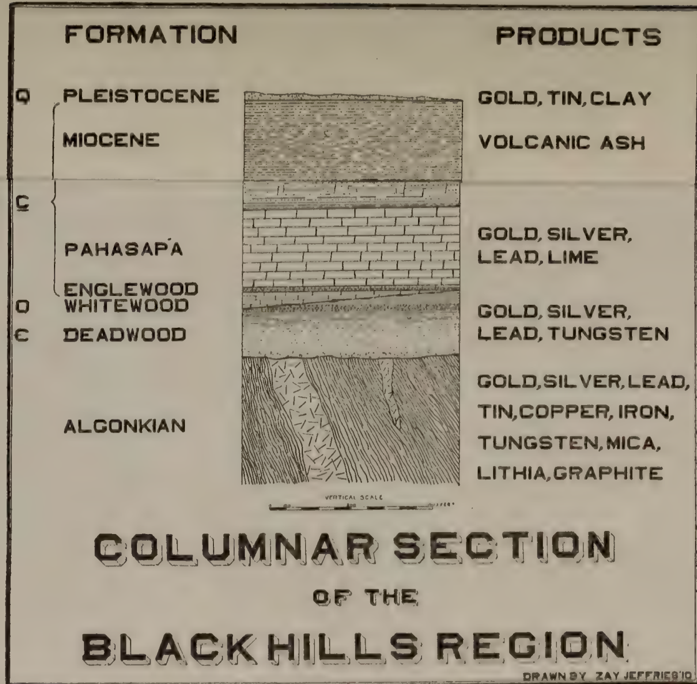
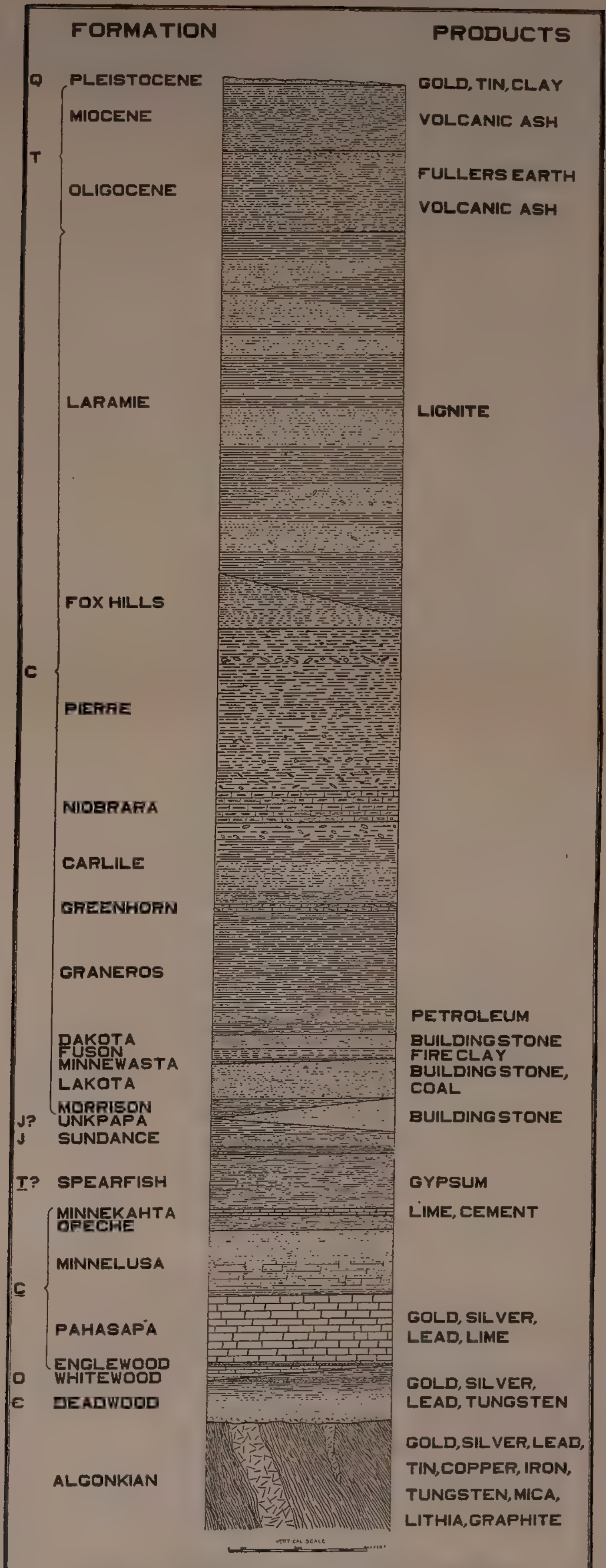
*I regret the seeming necessity of following conservative classification rather than joining present events with probable future conditions and adding the beautifully expressive term "Psychozoic era," the Age of Man, introduced by Prof. Joseph LeConte many years ago and used by him in the various editions of his Elements of Geology.



COLUMNAR SECTION OF THE BLACK HILLS REGION

DRAWN BY ZAY JEFFRIES '10



COLUMNAR SECTION OF THE BLACK HILLS REGION

Table of Geologic Divisions for the Black Hills Region.

Cenozoic	Quaternary	Recent alluvial (flood plain) deposits.	
		Older high-level gravels, sands, and clays.	
	Tertiary	Pliocene.	Not subdivided.
		Miocene	Nebraska Beds, etc. Arikaree.
		Oligocene	Brule. Chadron.
		Eocene	[Not represented.]
Mesozoic	Cretaceous	Laramie.	
		Fox Hills.	
		Pierre.	
		Niobrara.	
		Carlile.	
		Greenhorn.	
		Graneros.	
		Dakota.	
		Fuson.	
		Minnewasta.	
		Lakota.	
		? Morrison.	
	Jurassic	? Unkpapa. Sundance.	
	Triassic	? Spearfish.	
Paleozoic	Caboniferous		
	Permian	Minnehaha. Opeche.	
	Pennsylvanian-Mississippian	? Minnelusa.	
	Mississippian	Pahasapa. Englewood.	
	Devonian	[Not represented.]	
	Silurian	[Not represented.]	
	Ordovician	Whitewood.	
	Cambrian (Acadian)	Deadwood.	
Proterozoic	Algonkian	Not yet differentiated.	
Archeozoic		[Not represented.]	

The badland formations of the Black Hills region, from the earliest days of their exploration, have been recognized as of Tertiary age and of non-marine character. Their relation to the marine and non-marine deposits throughout the North American continent is shown in Figure 4 from Scott's Introduction to Geology, 1907.

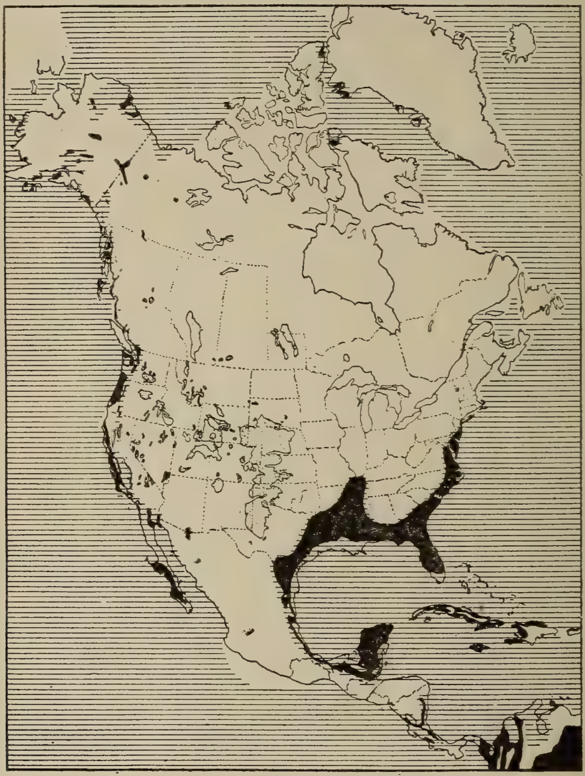


Figure 4—Map of North America in the Tertiary period. Black areas—known exposures of marine Tertiary; white areas—land; lined areas—sea; dotted areas—non-marine formations. After Scott.

The particular horizon within the Tertiary to which the various subdivisions should be referred has been less easy to determine. Leidy in his earliest studies of the extinct animals considered the beds as Eocene. Fuller study indicated to him and others a wider range in age than was first suspected and many features showed a later Tertiary character. As a result they became designated as Miocene and Pliocene, then as Lower Mio-

cene and Pliocene, the Miocene (or Lower Miocene) being often referred to as the White River group. Later as the methods of correlation became more refined and as representative fossils came more abundantly and in better condition from the hands of the collectors, giving better opportunity for comparison with similar fossils in other parts of the world, the lower beds were found to be equivalent to the Oligocene and the upper beds to the Miocene, chiefly Lower Miocene, the Oligocene being in many ways the more important. This is now the accepted correlation. Pliocene deposits are known to occur widely distributed in western Nebraska and thin sheets or outliers extend northward into the area under discussion. They have not been fully studied, but it is believed that they can not be of great lithologic importance.*

An important work of investigators has been to further sub-divide the deposits and to correlate in so far as possible the resulting subdivisions. Hayden early attempted a subdivision and with marked success so far as materials then at hand would allow. A complete restatement here of his section is perhaps not desirable, but a brief reference to it may serve a good purpose. Six beds were recognized. The oldest was designated as Titanotherium Bed A, and next above this was Turtle and Oreodon Bed B. Continuing in ascending order were Bed C, Bed D, Bed E, and Bed F. Titanotherium Bed A, now known in the literature as the Chadron formation or the Titanotherium zone, stands practically as designated more than fifty years ago by the author of the term. The Turtle and Oreodon Bed B, as outlined, has withstood the scrutiny of later investigators nearly as well as the lower bed, although a slightly different definition as to what shall be included has been found advisable. The beds above this are less uniform in character and their correlation has been the subject of much more discussion.

The present classification, shorn of some local and conflicting peculiarities, is given in the table on the following page. There seems little need for the purpose of this paper, in view of the fact that the various formations are individually described under Character of Deposits, to further detail the successive

*For recent discussion of this subject the reader is referred to the following papers: Cenozoic Mammal Horizons of Western North America by Osborn, with Faunal Lists of the Tertiary Mammalia of the West by Matthew, U. S. Geol. Surv., Bull. 361, 1909; and A Pliocene Fauna from Western Nebraska by W. D. Matthew and Harold J. Cook, Am. Mus. Nat. Hist., Bull. Vol. 26, pp. 361-414, 190'.

Generalized Section of the Badland Formations of the Black Hills Region.

Upper Miocene—50-200 ft.	Constitutes part of the deposits formerly designated as the Loup Fork group. Has at times been erroneously included with the Arikaree formation.		Nebraska Beds.	Procamelus Zone.
Middle Miocene— ——ft.	Has not been differentiated within the area.		(Sheep Creek Beds farther south.)	
Lower Miocene—600-900 ft.	Arikaree Formation.	(Nearly equivalent to what in the southeastern part of the region has been called the Rosebud beds. Constitutes part of the deposits formerly designated as the Loup Fork Group. Approximately same as Hayden's D.)	Harrison Beds.	Merycochoerus Zone with Daemonelix Sandstone.
			Monroe Creek Beds.	Chiefly Promerycochoerus Zone with Gering Sandstone. The lower beds are more or less transitional from the upper Oligocene.
Upper Oligocene—150-250 ft.	Brule Formation: Upper	(Equivalent to upper part of Hayden's C.)	Protoceras Beds.	Leptauchenia Zone (Plains fauna) with Protoceras sandstone (Forest and Fluviatile fauna)
Middle Oligocene—200-400 ft.	Brule Formation: Lower	(Equivalent to Hayden's B and lower part of C.)	Oreodon Beds.	Oreodon Zone (Plains fauna) with Metamynodon sandstone (Forest and Fluviatile fauna.)
Lower Oligocene—0-180 ft.	Chadron Formation:	(Equivalent to A of Hayden.)	Titanotherium Beds.	Titanotherium Zone.

steps taken in building up the classification. The table given indicates in concise form the results of the combined effort on the part of many investigators, and while some adjustment must still be made, particularly in the Miocene, it may perhaps in the main be taken as final. I have endeavored in this manner to put the chief facts in convenient analytical form for the student and the layman and at the same time have endeavored to see that brevity has not interfered in any material way with the rights or preference of any one, who by his careful study may have been instrumental in developing the separation and correlation of the formations as we now know them. Differentiation of the formations has been confined chiefly to the country southeast, south and southwest of the main Black Hills uplift. Farther north the deposits have been mostly eroded away, fossils are less abundant, and little determinative work has been possible.

The general stratigraphic relation of the formations to the closely related deposits found elsewhere in the west, is well shown in Figure 5 from Osborn's book, "Evolution of Mammalian Molar Teeth," 1907.

NATURE OF THE DEPOSITS

The geology of the northern part of the area represented on the accompanying map has not been fully studied, but reconnaissance trips by various geologists have served to indicate the general features. The fullest and most detailed account of the conditions in northwestern South Dakota is given by Prof. Todd, who spent two months in the region in 1895.

The badland formations in this part of the state and in the more immediate localities across the line in Montana and North Dakota are restricted to the higher buttes. Those in South Dakota known to be capped by Tertiary materials are: Short Pine Hills, Cave Hills, Slim Buttes, Haystack Butte, Castle Rock Butte, and Deers Ears Butte. It is possible that future study will disclose others.

The following observations are among those made by Prof. Todd: Short Pine Hills show approximately 285 feet of the Tertiary, the upper 260 feet being a fine grained white sandstone, with many small concretions. This is underlain by a stratum twenty-five feet thick, mostly concealed, but apparently a soft clay. Deers Ears, approximately thirty miles to the southeast, retains only six or eight feet, and this is a coarse gray conglomerate. About the same distance to the northeast

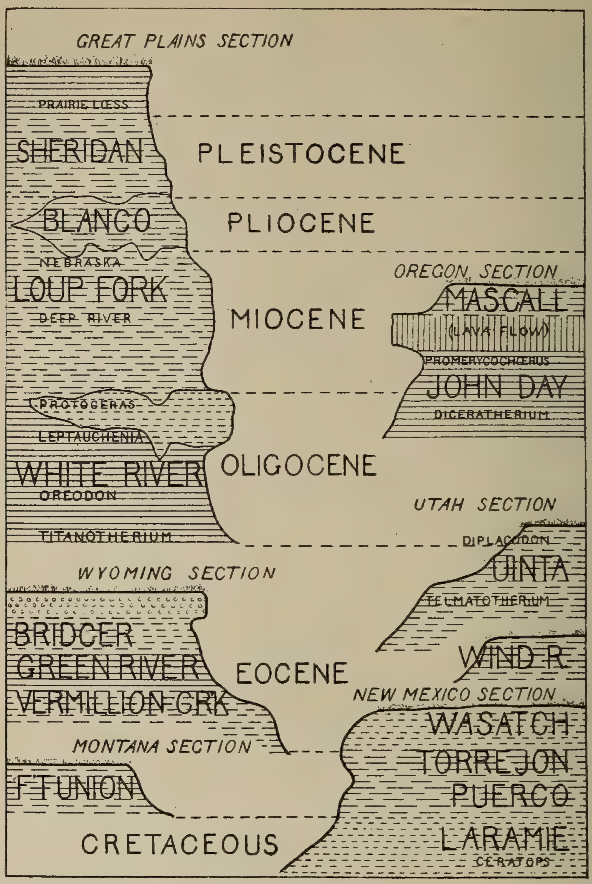


Figure 5—Diagram showing the chronological and stratigraphic succession of the Cretaceous, Tertiary and Pleistocene formations of the western states, in which fossil mammals are found. After Osborn.

Slim Buttes show at the northern end 240 feet, near the middle on the western side 180 feet, and at the southern end about 140 feet. The section on the north is made up of a soft white sandstone, 135 to 140 feet underlain by a 100-foot bed of dark to light colored contorted clays. The sections measured on the western side and at the southern end are more varied. It appears that these two sections may serve fairly well as representative for this part of the country, hence are given here in full.

Section Near Florman's on West Side of Slim Buttes.

Soil and soft white sandstone....................	20	feet
Hard layers of sandstone forming a cornice and a layer six inches thick at the top, very hard like flint	5	"
Sandy white clay, cracking polygonally above, shading into thin white sandstone below........	12	"
Massive white, fine sandstone with small globular concretions, translucent within, the rock showing efflorescence where not exposed to the weather. There are some layers of reddish color and some even shaly....................	60	"
Reddish flat concretions........................	1	"
Stratified, white sandstone.....................	6	"
Soft sandstone, full of vertical, stalactite-like concretions, redder below....................	6	"
Massive argillaceous sandstone, weathering into globular masses and containing small globular concretions	15	"
Slope mostly soft white sandstone..............	27	"
Gray clay with porous sandstone fragments and with several thin interrupted layers of sandstone obliquely laminated, usually dipping to the north.	18	"
Rusty clays and sand, some white places and occasional thin layers of limonite................	10	"
Total	180	feet

Section in the Southeastern part of Slim Buttes.

Clay, top of it flat with fragments of limestone...	9	feet
Coarse sandstone	2	"
Whitish clay	38	"
Light gray sandstone........................	4	"
Fine argillaceous sand rock.....................	50	"
Coarse sandstone	9	"
White argillaceous limestone, lower six inches full of fossils of fresh water shells, very hard and sonorous.. .. ..2 to	3	"
White clay	18	"
Sandy white clay..........................	8	"
Fragments of buhrstone or yellow flint with plant stems	1	"
Total	142	feet

Farther south, according to Darton, "Castle Rock is capped by 110 feet of Tertiary deposits lying on dark-gray clays. At the base are thirty feet of mostly fine white sandy massive clay, merging downward into five feet of grayish-green sandy clay. The upper 75 feet is of sandstone, mostly soft, but partly quartzitic, as a rule massive, but in places thin bedded and with a few pebbly layers. In some respects it resembles portions of the White River formation (Oligocene) of the Big Badlands, but the entire deposit or at least its upper member may be an out-

lier of the Arikaree. No bones were found to throw light on this question."*

Little attempt has been made north of the Hills to separate the Oligocene from the rocks of later Tertiary age, if such be present. The lithologic conditions seem too changeable and indefinite to be of positive service alone and there has been almost no opportunity for paleontologic investigation. Prof. Todd mentions the finding of Titanothere remains near Short Pine Hills, hence Oligocene strata must be present. Certain structural disturbances in some of the lower beds together with the character of the over-lying beds in certain places, particularly in Slim Buttes, seem to give some fair ground for division into Oligocene and Miocene, and Prof. Todd has indicated this in his paper. Corroborative proof of the accuracy of this division must, it seems, await the finding of fossils characteristic of the various formations.

Three small areas in the southwestern part of North Dakota are known to contain Oligocene strata, and one of these, White Butte, only thirty-five miles from Cave Hills, has afforded important fossils sufficient for detailed correlation. White Butte is beyond the boundaries of the accompanying map, but in view of its important bearing on the deposits in northwestern South Dakota, its seems proper to briefly describe it. The butte seems to have been first studied by Prof. Cope, who collected some fossils there in 1883. Mr. Earl Douglas, of the Carnegie Museum, spent some time in the locality in 1905, at which time he made a detailed section and collected many fossils. Among these were the remains of many rhinoceroses, including a number of complete skulls and several three-toed horses. Remains of crocodiles were also found. The rhinoceroses belong to the species *Aceratherium tridactylum* Osborn, and the horses to the two species *Mesohippus bairdi* (Leidy) and *Mesohippus brachystylus* Osborn.

Prof. A. G. Leonard, State Geologist of North Dakota, visited the locality in 1907 for further study.† The following is a section measured by Prof. Leonard:

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*Darton, N. H. Geology and Water Resources of the Northern Portion of the Black Hills and Adjoining Regions in South Dakota and Wyoming. U. S. Geol. Surv., Prof. Papers No. 65, 1909, p. 59.

†Leonard, A. G. North Dakota Geol. Surv. Fifth Biennial Rept. 1908, p. 67.

Section at White Butte.

11. Sandstone, rather fine grained, light greenish gray in color, weathering into a greenish sand, to top of White Butte	105	feet
10. Clay, gray to light greenish color	25	"
9. Clay, hard and compact, calcareous, light gray, almost white; forms hard ledges which make low vertical cliffs toward the top of the butte, and weathers irregularly	34	"
8. Clay, dark gray, calcareous; the line of separation between this clay and No. 7 is sharp and distinct, the clay being considerably darker than the underlying sandstone	46	"
7. Sandstone, light gray, rather coarse grained	20	"
6. Sandstone, very coarse grained and pebbly; in places the pebbles are so abundant as to form a conglomerate. Shows cross lamination. Pebbles composed of quartz, silicified wood, many varieties of igneous rock, among which porphyry is common, etc. Pebbles range in size up to two and three inches in diameter	26	"
5. Clay, very light gray, slightly sandy	5	"
4. Sandstone, light gray, very fine grained and argillaceous	5 1-3	"
3. Clay, light gray to white, slightly darker than No. 2; contains some white sand	10 1-2	"
2. Clay, very white and pure	6 1-2	"
1. Clay, white, containing some fine sand, hard and very tough when dry; rests directly on the sandstone of the Fort Union	14 1-3	"
Total	298	feet

Concerning the above section, Prof. Leonard says: "These deposits represent all three divisions of the White River group, the lower or Titanotherium beds, the middle or Oreodon beds, and the upper or Protoceras beds. In the foregoing sections Nos. 1 to 7 probably belong to the lower, Nos. 8 to 10 to the middle, and No. 11 to the upper division."

For a more detailed section and a fuller description of the extinct animals found, the reader is referred to the Annals of the Carnegie Museum, Vol. IV. 1908, and Vol V. 1909.

The deposits within the borders of the main Black Hills uplift have been more fully studied than those farther north, but with the exception of two unique little deposits near Lead and the much larger areas along the southeastern border connecting the Hills with the Big Badlands, they have not been differentiated sufficiently to admit of definite correlation.

On the higher tables of the Bear Lodge mountains the

materials consist largely of conglomerates and gravels interstratified with beds of sand and clay and occasionally impure fullers earth, similar to that of the Titanotherium beds elsewhere. The gravels and conglomerates contain many pebbles, cobbles, and even boulders of considerable size derived from the nearby older rocks, both sedimentary and igneous. The thickness ranges up to 200 feet or more. Near Missouri Buttes, west of the main Bear Lodge uplift, the material is usually a fine, massive, creamy white calcareous clay with thin bands or bunches of argillaceous limestone. The deposits here are known to be twenty or thirty feet thick and there is some indication that the thickness at the very base of the buttes on the northwest side may reach more than one hundred feet. All of these Bear Lodge beds, evidently of Tertiary age, are provisionally classed as Oligocene, but it should be borne in mind that not being continuously connected with deposits of known age elsewhere, and no fossils having been found in them, their exact horizon has not been certainly established.

A little deposit not well known, but of much interest, found near Lead City by Prof. Jenney about 1879 or 1880, deserves particular mention. This deposit does not outcrop at the surface, but was found in a prospect shaft about one-half mile southeast of Lead, at an elevation of 5,200 feet. The full extent of the deposit could not be determined, but it lies in a deep basin or channel eroded in the Algonkian slates, the latter outcropping on all sides within a radius of half a mile. Fortunately three nearly perfect skulls were found in the light-colored sandy clay beds penetrated by the shaft and these were all determined by Prof. Marsh as belonging to the species *Oreodon culbertsoni.* At a later time remains were found in light colored clay excavated in a tunnel not far from the shaft mentioned, and these were identified by F. A. Lucas as being the jawbone of a small Mesohippus and the skull and jaw of *Ischyromys typus.* All of these fossils indicate Oligocene beds similar to those of the Big Badlands.

The Tertiary deposits of the central and southern Hills within and near the main uplift, have been studied mainly by Mr. N. H. Darton. He identifies them as being of Oligocene age and has summarized their general character as follows:

"The deposits of the White River group (Oligocene) exhibit considerable diversity of composition. The principal material is a porous, crumbling clay of pale flesh color when dry,

but a light brown color when damp. Some portions of it are pale green when dry, or olive when wet. It is a hydrosilicate of alumina, with some admixture of sand and clay, being in reality fullers' earth, and different from ordinary clay in being much less plastic. In the lower beds of the group it merges into sand on the one hand, and into clay on the other. It is often associated with, or gives place to, coarse materials occupying channels or broad sheets. In the vicinity of Hermosa the principal material is coarse sandstone and conglomerate, mainly of dark brown color, which mantles extensive plateaus. On the high level ridge, north of Spring creek, there are coarse conglomerates which extend entirely across the hogback range. About Fairburn and to the westward, there are long channels filled with conglomerate consisting of limestone pebbles and a calcareous matrix. These extend up several of the depressions through the hogback range, either displacing the fullers' earth deposits, or being intercalated among them. The limestone pebbles appear to have been derived from Tertiary limestones, for they do not represent any of the Mesozoic or Paleozoic rocks of the Hills. On the higher lands in the Red Valley, between Hermosa and Rockerville, there is an extensive deposit of nearly pure limestone, giving rise to a high plateau of considerable extent. The total thickness of the beds is nearly thirty feet at some places, the limestone being underlain by fullers' earth. Limestones of various degrees of purity are abundantly intercalated in the fullers' earth deposits in the region west and southwest of Fairburn, lying in depressions on the older rocks. These limestones usually contain fresh-water fossils, mainly gasteropods, often in great abundance. The most southerly occurrence of the limestone is on the ridge a short distance northwest of the western entrance of Fuson Canyon, and on the high divide just north of Lame Johnny creek, and a short distance west of Fremont, Elkhorn and Missouri Valley (now the Chicago and Northwestern) railroad. There are extensive exposures of coarse materials of White River age in the railroad cuts through this divide south of Fairburn, where the materials are mainly cross-bedded coarse sands with a large proportion of gravel largely derived from crystalline rocks of the hills. The thickness of the White River deposits on the flanks of the Black Hills varies from a thin remnant to 200 feet or more. In the divide just south of Lame Johnny creek in the Red Valley, at a point ten miles southwest of Fairburn, over 200 feet were measured, consisting mainly of pale flesh-colored sandy clay and

fullers' earth. East of the Hills the White River group is usually divisable into two formations—the Titanotherium beds or Chadron formation below, and the Oreodon beds or Brule clay above. The Chadron formation consists of fullers' earth, light-gray, drab, pale-green or pinkish tints, traversed by channels filled with gray sandstone. At the base there is usually a bed of coarse gravel composed of rocks derived from the Black Hills. The Brule clay is a thickly laminated sandy clay of pale flesh and drab colors. * * * The following bones determined by Prof. F. A. Lucas, were obtained in beds high up on the flanks of the Black Hills west of Fairburn: *Oreodon culbertsoni, Poebrotherium wilsoni, Stylemus nebrascensis, and Hyracodon nebrascensis.*"*

Beyond the Cheyenne river, southeast, south and southwest of the main uplift, the deposits are thicker and more representative than elsewhere. They have there been more carefully studied paleontologically and the various beds have been defined with a considerable degree of completeness. It is possible to distinguish for this part of the region the several individual formations. The following sections and plate will serve as a good introduction to the more detailed description of the various subdivisions: The first section, page 35, from Wortman's stratigraphic table of the formations in the Big Badlands;† Figure 6, Darton's section, near Adelia, Nebraska, at the base of Pine Ridge;‡ Plate 4, Osborn's Idealized Bird's Eye View of the Big Badlands looking from near the Black Hills toward Porcupine Butte.§ This latter is a combination, slightly modified, of the stratigraphic table by Wortman, and the Columnar section from Osborn reproduced in Figure 8.

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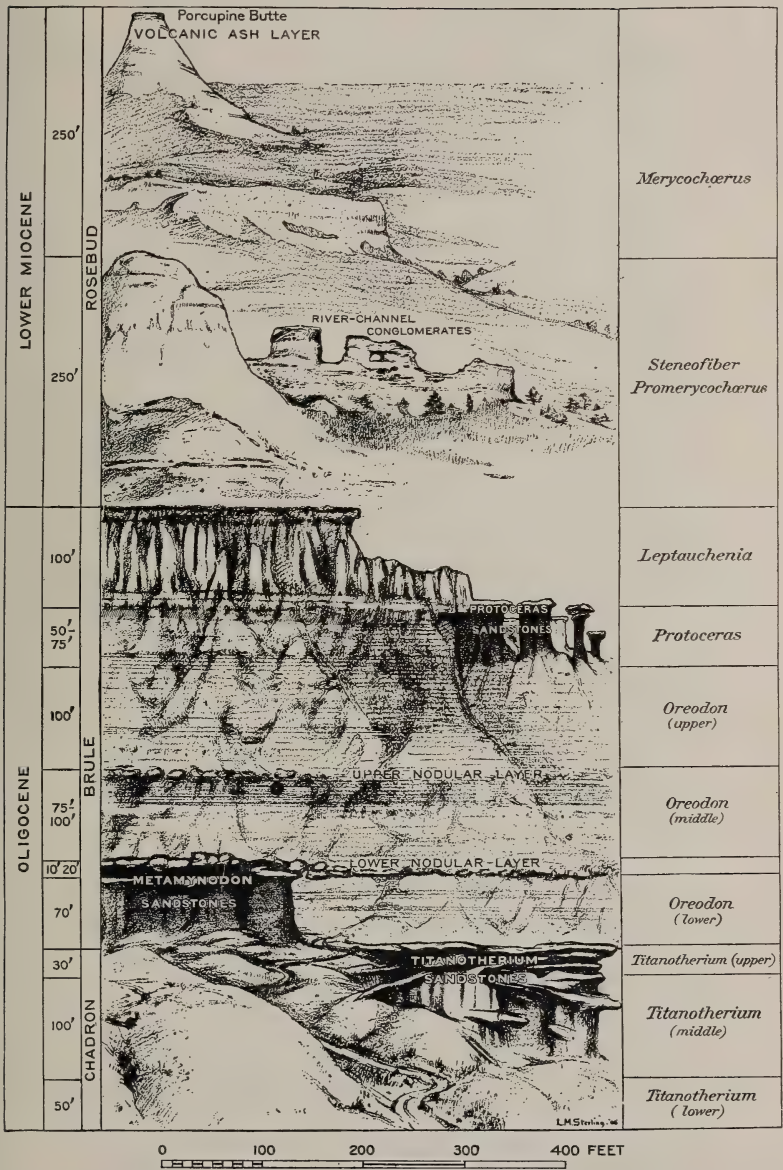
*Darton, N. H. Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming, U. S. Geol. Surv., Twenty-first Ann. Rept., Part IV, 1901, pp. 542-543.

†Wortman, J. L. On the Divisions of the White River or Lower Miocene of Dakota. Am. Mus. Nat. Hist., Bull. Vol. 5, 1893, pp. 95-105.

‡Darton, N. H. Preliminary Report on the Geology and Water Resources of Nebraska West of the One Hundred and Third Meridian. U. S. Geol. Surv., Nineteenth Ann. Rept., pt. IV, 1899, p. 757, and with slight modification, U. S. Geol. Surv., Prof. Paper No. 17, 1903.

§Osborn, H. F. Cenozoic Mammal Horizons of Western North America, U. S. Geol. Surv., Bull. No. 361, 1909.



Idealized bird's-eye view of the Big Badlands, showing channel and overflow deposits in the Oligocene and Lower Miocene. Looking southeast from the Black Hills. Osborn, U. S. Geol. Surv. Bull. No. 361.

Reproduction of one of the early views of the Big Badlands by Dr. F. V. Hayden, Am. Nat., 1882.

Photograph by O'Harra, 1910.

General view in the Big Badlands. Looking north from the Great Wall near Interior.

Geologic Section of the Big Badlands.

Approximate estimate thickness of the beds.		Characteristic species and general character of the rock.
Protoceras Beds	100 feet	Leptauchenia layer; nodule-bearing, pink-colored clays widely distributed.
	50-75 feet	Coarse sandstones, occupying different levels, not continuous.
Barren Clays (Now included with the Oreodon Beds.)	100 feet	Light colored clays.
Oreodon Beds	75-100 feet	Nodulous clay stratum. Bones white. Sandstones and clays. Bones rusty colored.
	10-20 feet	Oreodon layer; nodule-bearing, very constant and widely distributed. Numerous Oreodons and turtles imbedded in nodules. Bones always covered with scale of ferruginous oxide. 'Red layer' of collectors.
	50 feet	Metamynodon layer; sandstones, sometimes replaced by light colored barren clays. Bones usually rusty colored. Reddish gritty clay, sometimes bluish. Bones white.
(Now included with the Oreodon Beds.)	20 feet	Mingled remains of Titanotherium, Aceratherium and Mesohippus.
Titanotherium Beds	30 feet	Clays, sandstones and conglomerates.
	100 feet	Clays, toward the base often reddish, or variegated. The prevailing color, however, is a delicate greenish white. Bones are always light colored or white, sometimes rusty.
	50 feet	

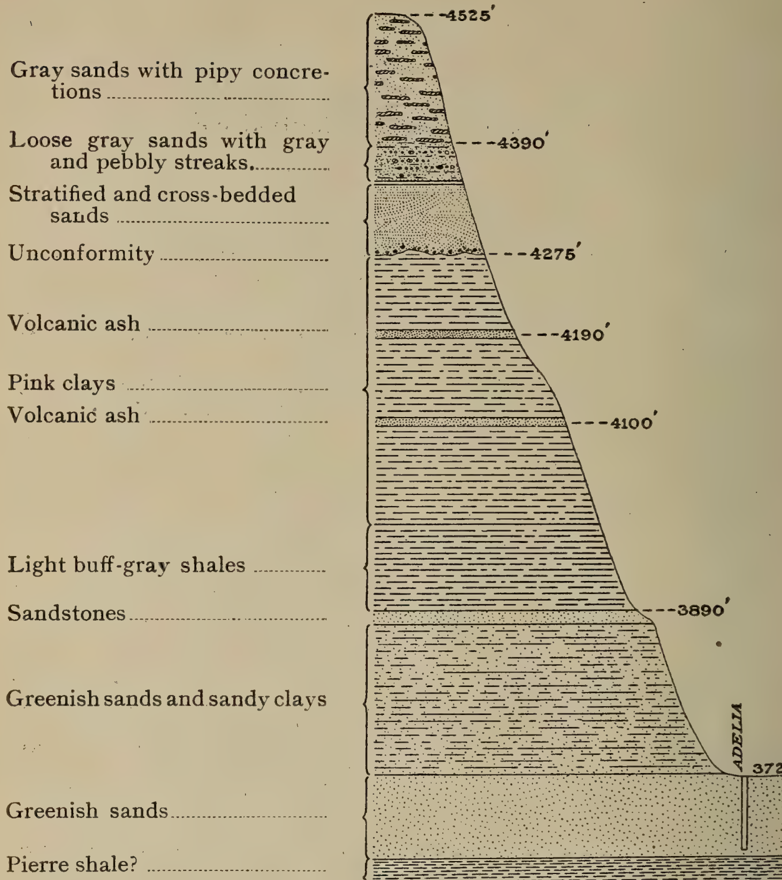


Figure 6—Section from Round Top to Adelia, Sioux county, Nebraska. Above Pierre shale to 3725 is Chadron, 3725 to 4275 is Brule, 4275 to 4390 is Gering, 4390 to 4525 is Arikaree. After Darton.

THE CHADRON FORMATION

The Chadron formation, better known by the much older term, *the Titanotherium beds,* from the name of the large extinct animals, whose bones occur in it so abundantly, receives its name from the town of Chadron in northwestern Nebraska. The formation is best developed and has been most studied in and near the Big Badlands of South Dakota, but is of importance along the northerly facing escarpment of Pine Ridge in South Dakota, Nebraska and Wyoming. Owing to the slight dip of the strata away from the Black Hills, the Pine Ridge

Photograph by O'Harra, 1899.

Figure 1. School of Mines camp near head of Indian Creek.

Photograph by O'Harra, 1899.

Figure 2. School of Mines Titanothere quarry, valley of Indian Creek. Sheep Mountain in the distance.

Photograph by O'Harra, 1899.

Figure 1. General view of Titanotherium Beds, Valley of Indian Creek.

Photograph by O'Harra, 1909.

Figure 2. Erosion detail of Titanotherium Beds near Big Foot Pass.

outcrop, lying as it does at the base of the high escarpment, passes quickly beneath younger formations and leaves only a long narrow east-west band for observation. In and near the Big Badlands the White and Cheyenne rivers and their tributaries have cut deeply into and across the deposits, and there the Chadron is exposed over a large territory. The beds are known to underlie an extensive area of later formations within and beyond the Black Hills region and are well exposed in the valley of North Platte river in western Nebraska, and of South Platte river in northeastern Colorado.

The formation is made up chiefly of a sandy clay of light greenish-gray color, with generally coarser sandy materials at or near the bottom, including sometimes deposits of gravel or conglomerate several feet thick. The beds immediately above the gravels are often of a yellowish, pinkish, reddish, or brownish color, and Mr. Darton states that in northwestern Nebraska, near Adelia, the red color is especially prominent. Aside from this the color in the main is a greenish white, the green showing as a very delicate tinge on weathered slopes, but a distinctly deeper olive green in fresh exposures. The clays sometimes partake of the nature of fullers' earth, but generally they contain more or less sand. In most of the beds little cementing material is present, although the clays are often quite compact. Occasionally thin persistent bands of knotty, grayish limestone or lime clay concretions are found. These weather to a chalky white, and although seldom prominent individual bands may sometimes be traced over considerable areas. Concerning the sandy layers within the Big Badlands, Hatcher says:

"The sandstones are never entirely continuous, and never more than a few feet thick. They present every degree of compactness, from loose beds of sand to the most solid sandstones. They are composed of quartz, feldspar, and mica, and are evidently of granitic origin. When solidified the cementing substance is carbonate of lime.

"The conglomerates, like the sandstones, are not constant, are of very limited vertical extent, never more than a few feet thick. They are usually quite hard, being firmly held together by carbonate of lime. A section of the beds taken at any point and showing the relative position and thickness of the sandstones, clays and conglomerates is of little value, since these vary much at different and quite adjacent localities."*

*Hatcher, J. B. The Titanotherium Beds. Am. Nat., Vol. 27, 1893, pp. 204-221.

The total thickness of the formation within the Big Badlands is approximately 180 feet. Hatcher and others subdivide the formation in that locality as follows: Lower, 50 feet; Middle, 100 feet; Upper, 30 feet. The sub-divisions are based on the nature of the Titanotheres found at the various horizons. Along Pine Ridge the formation is much thinner. Darton gives it as approximately 30 to 60 feet.

THE BRULE FORMATION

The Brule formation, like the underlying Chadron formation, outcrops chiefly in the Big Badlands and along the northward facing escarpment of Pine Ridge. As now commonly understood, it may for the Big Badlands be best considered under its two subdivisions, namely, the Oreodon Beds, constituting the lower part, and the Protoceras Beds, constituting the upper part.

The Oreodon Beds. The Oreodon beds, so named because of the abundant remains of Oreodons found in them, are made up chiefly of massive arenaceous clays, lenticular sandstones, and thin layers of nodules. A particular feature of the beds is the color banding. The general color is a gray or faint yellow, but this is often much obliterated by horizontal bands showing some shade of pink, red or brown. They are present in greater or less prominence over large areas, particularly in the Big Badlands, and in places become a rather striking feature. Their thickness varies from an inch or less to occasionally several feet. Sometimes they are repeated in rapid succession without great contrasts in color. More often a few bands stand out with prominence, especially if moistened by recent rains and, seen from some commanding point, may be traced for long distances.

The sandstones being of a lenticular nature are often absent or of little consequence, but in many localities they reach considerable thicknesses. One series near the middle of the bed is of particular importance. It reaches in the Big Badlands a thickness of twenty feet or more, and according to Wortman, covers an area approximately twelve miles in length and a mile or a mile and a half in width. It contains fossil remains in abundance of the ancestral rhinoceros, Metamynodon, hence is commonly known as the Metamynodon sandstone.

Of the nodular layers, one just above the Metamynodon sandstone is of paramount importance. For description of this I quote from Mr. Wortman: "There is one layer found in the Oreodon Beds which is highly characteristic and is perhaps more constant and widely distributed than any other single stratum

Photograph by O'Harra, 1899.

Figure 1. Oreodon Beds west of Sheep Mountain Table.

Photograph by O'Harra, 1899.

Figure 2. Oreodon Beds, valley of Indian Creek.

Photograph by O'Harra, 1899.

Figure 1. Protoceras Beds near top of Sheep Mountain.

Photograph by O'Harra, 1899.

Figure 2. Protoceras Beds near top of Sheep Mountain.

in the whole White River (Oligocene) formation. This is a buff-colored clay carrying numerous calcareous nodules in which are imbedded remains of turtles and oreodons. The fossils are almost invariably covered with a scale of ferruginous oxide when first removed from the matrix, and are of decidedly reddish cast. Upon this account this stratum is known to the collector as the 'red-layer.' It is situated somewhere between 40 and 50 feet above the top of the Titanotherium beds and can almost always be easily identified. It varies in thickness from 10 to 20 feet, and in some rare instances it is replaced by sandstone. I have also found it without the nodules in places, but this is also quite a rare occurence."*

Another tolerably constant fossiliferous nodular layer occurs at from 75 to 100 feet above the nodular layer just described. This higher horizon was provisionally considered as marking the top of the Oreodon beds. The present tendency is to extend the Oreodon Beds upward so as to include the series of non-fossiliferous clays about 100 feet thick, lying just above the upper nodular layer. The total thickness of the beds in the vicinity of Sheep Mountain is from 250 to 300 feet. The stratigraphy in Pine Ridge differs in some important respects lithologically from that of the Big Badlands and the exact equivalent there of the Oreodon beds does not yet seem clear.

The Protoceras Beds. The Protoceras beds, earlier considered as part of the Oreodon Beds, were first differentiated by J. L. Wortman as a result of field work done during the summer of 1892 for the American Museum of Natural History. The name is derived from the characteristic and highly interesting extinct animal, the Protoceras, which occurs in the sandstones of these beds in considerable abundance.

Lithologically the beds are made up of isolated patches of coarse, lenticular sandstones, fine-grained clays, and nodular layers. The sandstones occur at different levels and are usually fossiliferous. They are seldom continuous for any great distance and often change abruptly into fine-grained barren clays. Immediately overlying the sandstones there is a pinkish colored nodule-bearing clay, containing abundant remains of Leptauchenia and other forms, hence the name Leptauchenia zone often used in connection with these beds. The Protoceras beds have been

*Wortman, J. L. On the Divisions of the White River or Lower Miocene of Dakota. Am. Mus. Nat. Hist., Bull. Vol. 5, 1893, pp. 95-105.

clearly differentiated only in the Big Badlands. Elsewhere the lithologic conditions do not generally serve to indicate their presence, hence if they occur outside of the Big Badlands, the determination of their areal distribution must in a large measure await the study of the paleontologist. The total thickness of the beds, including with them the Leptauchenia clays, is approximately 150 to 175 feet.

THE ARIKAREE FORMATION

The Arikaree formation, first designated as such by Darton, receives its name from the Arikaree Indians, who were at one time identified with the area in which it is most largely developed. Its greatest development is in Pine Ridge and southward. It lies uncomformably on the Brule and in places overlaps the margins of that formation.

The Arikaree is largely a soft sandstone, varying in color from white to light gray. Calcareous concretions occur throughout the formation in abundance. They are usually of cylindrical form and are often more or less connected into irregular sheets. It is to this feature especially that the Pine Ridge escarpment and other prominent topographic features of that part of the country are due. For the manner of development of these concretionary forms, the reader is referred to the discussion of concretions and sand-calcite crystals elsewhere in this paper.

The Arikaree has not been carefully defined for all the area where it has been found, and owing to the variable nature of the formation in different localities a number of terms in this connection need to be referred to and defined. Darton in his studies in western Nebraska some years ago, differentiated certain sands and sandstones, lying below the typical Arikaree deposits, as the Gering formation. These sands and sandstones are not very abundantly developed within the area covered by the Black Hills map, but are of importance farther south. More recent study seems to show that much of this material is little more than non-continuous river sandstones and conglomerates that traverse the lower Arikaree clays and occupy in places irregular channels in the partly eroded upper Brule formation, the relation to the Arikaree clays being in such places much as that of the Titanotherium, Metamynodon and Protoceras sandstones to the clays in which they severally occur. The general tendency at present seems to be to consider them as a special depositional phase of the lower part of the Arikaree. According to Hatcher, the Arikaree in Sioux County, Nebraska, and Converse County,

Wyoming, is lithologically and faunally divisable into two easily distinguishable horizons, namely, the Monroe Creek beds, below, and the Harrison beds above.

The Monroe Creek Beds. The Monroe Creek beds, Hatcher states, are well shown in the northern face of Pine Ridge at the mouth of Monroe Creek Canyon, five miles north of Harrison, where they overlie the Gering sandstones, and are composed of 300 feet of very light colored, fine-grained, not very hard, but firm and massive sandstones. The thickness decreases rapidly to the east and increases to the west. The beds are generally non-fossiliferous, though remains of Promerycochoerus are found in it, hence the name Promerycochoerus zone.

The Harrison Beds. The Harrison beds receive their name from Harrison, in the vicinity of which town the beds are well exposed. As stated by Hatcher, they are composed of about 200 feet of fine-grained, rather incoherent sandstones, permeated by great numbers of siliceous tubes arranged vertically rather than horizontally. They are further characterized by the presence, often in great abundance, of those peculiar and interesting, but as yet not well understood, fossils known as Daemonelix, (hence called Daemonelix beds by Barbour, who first studied them), and by a considerable variety of fossil mammals belonging to characteristic Miocene genera.*

Later investigation has shown that in some places the division is not readily made on lithologic features alone, but that the formation can in all places be separated faunistically into lower and upper levels as indicated. The following section by

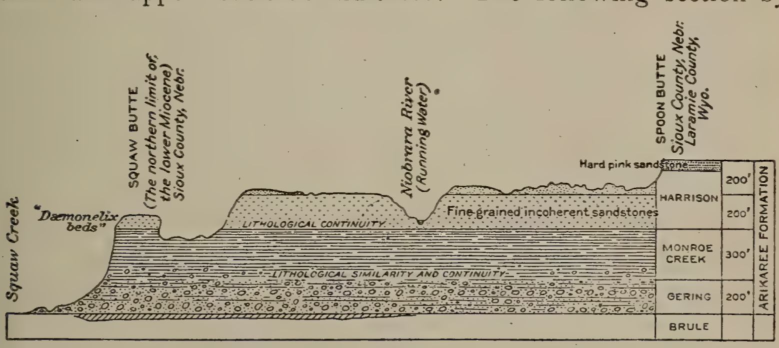


Figure 7—Diagrammatic section of the Arikaree on the Nebraska-Wyoming line west of Harrison. After Osborn modified from Peterson, 1906-09.

*Hatcher, J. B. Origin of the Oligocene and Miocene Deposits of the Great Plains. Am. Phil. Soc., Proc. Vol. 41, 1902, p. 117.

Osborn, modified from Peterson, shows the relations on the Nebraska-Wyoming line west of Harrison.*

The Rosebud Beds. The Arikaree has been studied with much care near Porcupine Butte and farther east on White river by representatives of the American Museum of Natural History. Matthew and Gidley, who first collected fossils there, designated the series of strata as the Rosebud beds. These beds are believed to be approximately equivalent to the Arikaree formation as the latter is now coming to be understood, but exact relations have not yet been fully determined over any very large section of the country. Matthew describes the beds in their typical eastern locality as follows: "The western part of the formation attains a thickness estimated at 500 feet on Porcupine creek, a southern tributary of White river. The base is taken at a heavy white stratum which appears to be identical with the stratum capping the White River formation on Sheep Mountain in the Big Badlands. This stratum can be seen extending interruptedly across the river to Sheep Mountain, about twenty miles distant, capping several intervening buttes and projecting points of the underlying formation. The Rosebud beds at the bottom approximate the rather hard clays of the upper Leptauchenia beds, but become progressively softer and sandier towards the top, and are capped at Porcupine Butte by a layer of hard quarzitic sandstone. Several white flinty, calcareous layers cover the beds, one of which, about half way up, was used to divide them into Upper and Lower. The stratification is very variable and inconstant, lenses and beds of soft fine-grained sandstone and harder and softer clayey layers alternating with frequent channels filled with sandstones and mud-conglomerates, all very irregular and of limited extent. The hard calcareous layers are more constant. A bed of volcanic ash lies near the top of the formation, and there may be a considerable percentage of volcanic material in some of the layers further down . These volcanic ash beds should in theory be of wide extent, and may be of considerable use in the correlation of the scattered exposures on the heads of the different creeks—a very difficult matter without their aid.

The beds form the upper part of the series of bluffs south of White river on the Pine Ridge and Rosebud Reserva-

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*U. S. Geol. Surv., Bull. No. 361, 1909, p. 73.

Photograph by O'Harra, 1899.

Figure 1. Looking south toward Sheep Mountain across top of Sheep Mountain Table.

Photograph by O'Harra, 1899.

Figure 2. Looking southeast toward Sheep Mountain from Valley of Indian Creek.

Photograph by O'Harra, 1910.

Looking west along the Great Wall, from Saddle Pass near Interior. Protoceras Beds above. Oreodon Beds below.

Photograph by O'Harra, 1910.

Detail of Great Wall north of Interior. Chiefly Protoceras Beds.

Photograph by O'Harra, 1910.

Detail of Great Wall north of Interior. Chiefly Protoceras Beds.

tions, and are exposed in the upper part of the various tributary creeks."*

For a section of these beds see Figure 8, from U. S. Geol.

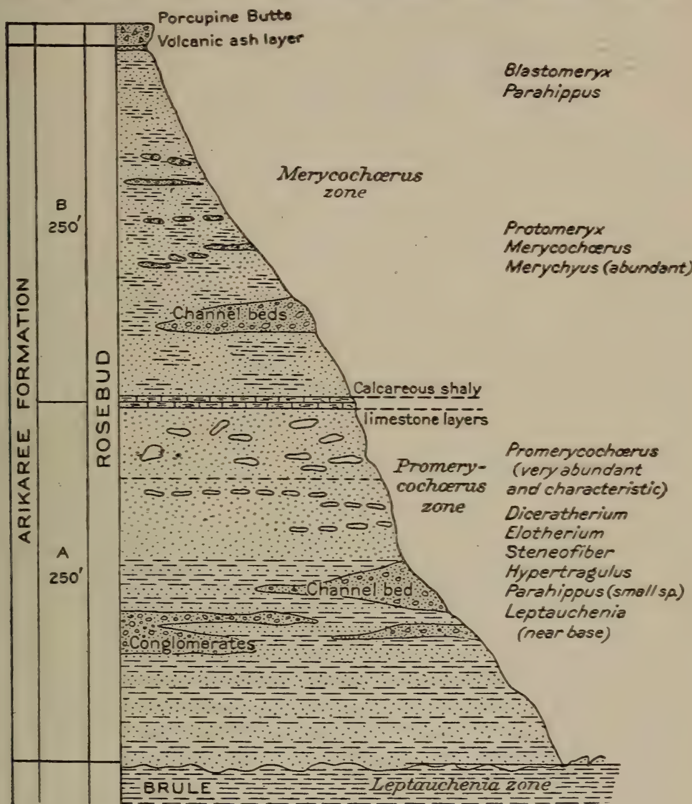

Figure 8--Columnar section from Porcupine Butte northward toward White River, as observed by Matthew & Thomson, 1906. Osborn, 1909.

Survey Bulletin No. 361, p. 70, Cenozoic Mammal Horizons of Western North America, etc., by Osborn and Matthew.

THE MIDDLE MIOCENE

The Middle Miocene, so far as I am aware, has not been positively identified within the area covered by the Black Hills map, but strata of this age have been studied fifteen or twenty miles south-southwest of Agate Springs, and they have there yielded a limited fauna. Matthew and Cook designate them as

*Matthew, W. D. A Lower Miocene Fauna from South Dakota. Am. Mus. Nat. Hist., Bull., Vol. 23, 1907, pp. 169-219.

the Sheep Creek beds, and describe them briefly, as follows: "They consist of soft fine-grained sandy 'clays' of a light buff color, free from pebbles, and containing harder calcareous layers. Their thickness is estimated at 100 feet. Near the top is a layer of dark-gray volcanic ash, two feet thick."*

THE UPPER MIOCENE

The Nebraska Beds. The Nebraska beds, so named by Scott, are represented in various areas not yet carefully mapped along the Niobrara river, where they immediately overlie the Harrison beds. Farther south they pass beneath the Oglalla formation, which covers so much of western and southwestern Nebraska. They have been studied by Hatcher and by Peterson.† Hatcher describes them as consisting of a series of buff colored sandstones of varying degrees of hardness and unknown thickness, with occasional layers of siliceous grits, which protrude as hard undulating or shelving masses from the underlying and overlying softer materials. Peterson states that the thickness cannot be greater than 150 or 200 feet, and he gives a section near the Nebraska-Wyoming line showing only 70 feet. The beds have afforded many interesting fossils of vertebrates, and Osborn states that the fauna is one of the best known, most widely distributed, and most characteristic in all the Tertiary series.

CONCRETIONS AND SAND-CALCITE CRYSTALS

A concretion is a spherical, cylindrical, elliptical, or nodular body produced by the tendency of certain mineral constiuents to orderly aggregate about a common center within an embedding rock mass. The discovery in the Badlands several years ago of what are known as "sand-calcite crystals" has added greatly to our knowledge of concretionary development and has served well to indicate the local conditions with reference to these abundant and interesting forms.

Concretions vary greatly in size, shape, composition, manner of distribution and method of growth. They are common in the Black Hills region. In some of the Cretaceous and Ter-

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*Matthew, W. D, and Cook, H. J. A. Pliocene Fauna from Western Nebraska. Am. Mus. Nat. Hist., Bull., Vol. 26, pp. 361-414.

†Hatcher, J. B. Origin of the Oligocene and Miocene Deposits of the Great Plains. Am. Phil. Soc. Proc., Vol. 41, 1902, pp. 113-131.

Peterson, O. A. Osteology of Oxidactylus. Carnegie Museum Annals, Vol. 2, 1903-'04, pp. 434-476.

Foote Mineral Co., Phila.

Sand-Calcite Crystals from the Miocene of Devils Hill.

tiary beds of the plains country they may be found in prodigious numbers. They occur in many places and in various horizons in the badland formations and of all sizes up to several feet in diameter. Any horizon which contains the concretions at all is likely to contain many of them and often they coalesce horizontally and form continuous strata. More frequently they are separate and, being harder than the surrounding material, they often tend under the influence of erosion to become the caps of earth pillars. The material of which they are made is generally an arenaceous clay with calcium carbonate as a cementing material, but iron oxide is often times present in considerable quantity.

The sand-calcite crystals were first studied by Prof. E. H. Barbour, of the University of Nebraska, in 1893. Professors S. L. Penfield and W. E. Ford of Yale University, in 1900, described a few additional forms. Later in the same year, Prof. Barbour described the crystals more fully and gave also a brief description of the locality, the geology, and the mode of occurrence, and showed the relation of the crystals to ordinary concretions.*

The crystals are made up of approximately sixty per cent of sand and about forty per cent of calcium carbonate. The former occurs as an inclusion, while the latter, the mineralizing agent, is the crystal proper. The size varies in length from a quarter of an inch or less to fifteen inches. Plate 15 shows several characteristic forms.

The crystals occur chiefly in the Arikaree formation, which is largely a soft sandstone. Much of the rock is in concretionary form, and not a little of it is in cylindrical or pipe-like masses, often many feet or yards in length. These, according to Barbour, often disclose evidence of some internal molecular or crystalline arrangement and weathered specimens not infrequently show a radiate or rosetted structure, due to the tendency of lime-salts to crystallize according to the laws governing calcite as far as the interference on the part of the sand grains will allow.

The first discovered and most noted locality is at Devils Hill, near Corn creek, about twenty miles south of White river

*For a still later discussion, including description of slightly different shaped crystals and a record of the distribution and geologic range of deposits of this character, the reader is refered to the following: Barbour, E. H., and Fisher, C. A. A New Form of Calcite-Sand Crystal. Am. Jour. Sci., Vol. 14, 1902, pp. 451-454.

in Washington County, Pine Ridge Indian reservation, South Dakota. Concerning their occurrence here, Prof. Barbour, who has visited the locality, says: "The mode of occurrence of these crystals seems most unusual and remarkable. In a bed of sand scarcely three feet thick, and so soft as to resemble the sand on the seashore, occur these crystals in numbers which can best be figured in tons. We dug them out with our bare hands. They are mostly single crystals, with numerous doublets, triplets, quadruplets, and multiplets. In other words every form from solitary crystals to crowded bunches and perfect radiating concretions were obtained. It was a matter of special interest in the field to note that at the bottom of the layer the bulk of these sand-lime crystals are solitary; one foot higher there is an evident doubling of the crystals, until within another foot they are in loosely crowded clusters. a little higher in closely crowded continuous clusters, pried out in blocks with difficulty; still higher they occur in closely crowded concretions in contact with one another, making nearly a solid rock. A little higher this mineralizing process culminates in pipes, compound pipes, and solid rocks, composed wholly of crystals, but so solidified that their identity is lost, and is detected only by a certain reflection of light, which differentiates the otherwise invisible units by showing glistening hexagonal sections. There could not have been a more gradual and beautiful transition, and all confined to a bed six or eight feet in thickness."*

The relation of the sand-calcite crystals to the Arikaree concretions, as indicted above, discloses an important step in the development of concretions in general, and doubtless to some such cause as this crystallographic tendency is due the development of the concretions of other strata, such as the Protoceras beds and the Oreodon beds.

SANDSTONE DIKES AND CHALCEDONY VEINS

Dikes and veins are ordinarily elongate, vertical, or nearly vertical rock or mineral masses occupying fissures in a pre-existing rock. The filling body, if intruded as an igneous rock while in the molten condition, is commonly referred to as a dike. If filled in by slow process of deposition from aqueous solution it is known as a vein. It is now recognized that fissures sometimes become filled with clastic material derived from adjacent or near-

*Barbour, E. H. Sand Crystals and their Relations to Certain Concretionary Forms. Bull. Geol. Soc. Am., Vol. 12, 1901, pp. 13-18.

by rock masses without any immediate influence either of heat or of solvent action. These clastic bodies are known as dikes also.

Until recent years, but few instances of clastic dikes had been observed, and geologists appear to have overlooked the earliest statement of their occurrence in the Badlands. Prof. F. V. Hayden says that in May, 1855, about ten miles northeast of Eagle Nest Butte, he observed "a vertical seam of fine-grained sandstone passing through the different strata for several hundred yards, varying in thickness from forty to thirty inches. Sometimes this vertical seam is left standing, the more yielding calcareous marl having been washed away from either side, and thus it forms a high perpendicular wall, having much the appearance of mason work. It is composed of a fine, light gray grit, and is doubtless due to the infiltration of fine sediment in a fissure in the strata."*

Two years later, October 8, 1857, Prof. Hayden found a similar dike between the Cheyenne river and White river, made up of fine blue grit and vertical to the enclosing strata. In connection with this he states that a large number of these "curious seams" occur at different localities.† It is to be noted that Prof. Hayden did not confuse these with the far commoner chalcedony veins, for he says (October 7) that on the left side of the Cheyenne, fifteen miles above the mouth of Bear creek, "Disseminated all through the Oreodon bed in every direction are thin seams of silex in the form of chalcedony."

Many years later Prof. Robert Hay of Kansas, described two dikes near Chadron. One of these averages ten inches in thickness, but to this should be added two and one-half to five inches on each side, this latter material being made up of vertically laminated and fluted clays. Its traceable length is 120 feet, the direction N48E. The other dike averages thirteen inches thick, plus three inches of vertically fluted clays on each side and is traceable 100 feet, the direction N70E. Prof. Hay regarded the dikes as having been intruded from below and compared them to the phenomena of mud volcanoes.‡

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*Hayden, F. V. Notes on the Geology of the Mauvaises Terres of White River, Nebraska (now South Dakota) Proc. Phil. Acad. Sci., 1857-8, p. 156.

†Hayden, F. V. On the geology and natural history of the Upper Missouri. Trans. Am. Phil. Soc., Vol. 12, 1862, pp. 30-31.

‡Hay, Robert. Sandstone Dikes in Northwestern Nebraska. Bull. Geol. Soc. Am., Vol. 3, 1892, pp. 50-55.

Mr. J. B. Hatcher in 1893 recorded the great abundance of chalcedony veins in the Titanotherium beds and states that they occur only in certain localities of limited area, never more than a few square miles in extent. He does not mention dikes. He attributes the chalcedony filled fissures to shrinkage caused by the gradual dissipation of the water that has been entrapped during the process of deposition and thus necessitates contraction within the sediment and considers that the vertical fissures thus formed beneath the original surface were later filled by chalcedony, occasionally calcite or Iceland spar, dissolved out of the overlying beds by heated waters percolating through them.*

In 1894 Mr. E. C. Case found many dikes and veins in the Badlands, and in the American Geologist of the following year gives the results of his observation. He says the sandstone of the dikes in the Oreodon beds is not hard, but soft and friable, and seldom shows much weather resisting tendency. The color of the dikes is a light green and easily recognized as identical with that of the greenish Metamynodon sandstone found at a lower level. He adds also that the material in the dikes of the Titanotherium beds is universally from some strata below. He describes the dikes as commonly perpendicular and extending in a straight line across the country, but without any common direction or parallelism. Some of the dikes were traced continually for more than a mile, the thickness seldom reaching more than three inches. Reference is made to others reaching as much as eighteen or twenty inches.

Concerning the veins he says: "Where the veins of chalcedony occur alone, they are so perfectly analagous in form and position with the dikes as to make it evident that the joints and cracks they occupy are of the same origin as those of the dikes. * * * From their hardness they resist weathering a great deal longer than the soft clays and stand up in jagged lines above the surface. When the clay around is removed and the support fails, pieces are broken off from the thin seams and fall on the neighboring clays; thus whole hills are covered with small sheets of quartz and are protected as by a shingle roof from the action of rain. * * * When the veins meet and cross they do not penetrate and destroy each other, but fuse, and perfect homogenous crosses were obtained from localities of such intersection."

Referring to instances where the dike and vein features were closely associated, he says: "In the cases where the dikes

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*Am. Nat. Vol. 27, 1893.

are connected with the chalcedony crystals the veins may exist on one or both sides of the intruded material between it and the clay walls of the crack. The absence of the crystals from one side or the other is not a local accident, but seems constant for large areas. In every case where it occurs on one or both sides of the core, the crystals have a perfect vein structure, presenting a flat surface to the core or dike and one to the clay wall, and meeting irregularly in the middle."

As to the method of formation, Mr. Case concludes: "The dikes of mud and sand occupy pre-existent cracks which were filled by intrusions below by water and suspended material. The water was forced into the cracks from porous layers either by hydrostatic pressure or by that of the superincumbent strata, probably both movements. They are in all probability both mud cracks and cracks formed by seggregation of the clays around local centers. The veins of chalcedony were formed by the entrance into similar origin as those containing the dikes, of silicated waters. The cracks were already filled more or less with water and sand. The thinning out of the seams from above downward indicates that the silicates filtered in from above."*

In the same year, 1894, Prof. Todd observed a number of dikes along the great wall near Sage creek and "near Black Postoffice in the south part of Ziebach county" on White river. Near Sage creek he found two dikes crossing each other at a small angle running nearly east and west. Across them were two others nearly north and south. They were found to vary in width from six to eight inches. The middle portions were columnar jointed, the outer portions perpendicularly fluted and showed other signs of upward motion of the mass. Prof. Todd coincides with Prof. Hay in the belief that the fissures have been produced by earthquake disturbances and agrees with both Prof. Hay and Prof. Case in considering that the material was intruded fro mbelow.†

Now that the badland formations have been more widely studied, it is known that dikes and veins cut the formations abundantly in many places and an observant visitor will often find them an interesting feature of the country.

In 1899 I found five or six miles northwest of Sheep Mountain, near the northeastern side of Indian draw, a dike of coarse

*Case, E. C On the Mud and Sand Dikes of the White River Miocene. Am. Geol., Vol. 15, 1895, pp. 248-254.

†Todd, J. E. A Preliminary Report on the Geology of South Dakota. S. D. Geol. Surv., Bull. No. 1, p. 106, 1894.

grit of a distinctly conglomerate nature, occasional pebbles, ranging up to nearly one inch in diameter. This dike where observed, projects in places twelve to eighteen inches above the general surface, is six to eight inches thick and is exposed in a straight line for a distance of several rods. The general nature of this dike is the same as in the other dikes described, but the conglomerate character so far as I am aware, has not been recorded elsewhere in the Badlands. A view of this dike is given on Plate 19.

It is interesting in this connection to note that dikes similar to those in the badland formations have been observed in the Cretaceous shales near the main Black Hills uplift, and Mr. Darton in describing them indicates that the material came from below, and that the dikes were not all formed at the same time and that at some points the shale on either side of the dike is deflected abruptly downward for a few inches.*

GEODES

Geodes are spheroidal masses of mineral matter formed by deposition of crystals from some mineral solution on the walls of a rock cavity. The growth is constantly inward toward the center. If the process of deposition has continued sufficiently long, the crystals reach across the depositional space, interlock with each other and the geode becomes solid. Often the crystals project only part way, leaving a considerable cavity and then the geode when broken presents a crystal lining of much beauty and interest. Commonly the geodes are more or less siliceous, especially in the outer portions and, resisting weathering better than the enclosing rock mass, may often be found freed from the matrix lying on the disintegrating surface. Not infrequently crystal fragments become detached within the shell, and these, striking against the inner walls when the geode is shaken, serve to make a sound. For this reason the geodes are often referred to locally as rattle stones.

Many geodes have been collected from the Big Badlands, but little is known of their occurrence or origin. The diameter varies from one inch or less to several inches. The prettiest ones of rather small size are said to be found near Imlay. Much larger ones occur near the mouth of Medicine Root creek. Those that have come under my observation have commonly an irregular shell of chalcedony more or less filled with bright clear

*Edgemont Folio, p. 5, column 4.

cut white or colorless quartz crystals, the latter varying from microscopic size to one-half inch or more in length. The finer white crystals much resemble white sugar, hence the name sugar geodes. Selenite, crystalized gypsum, is occasionally present. The origin of the geodes is doubtless closely connected with the origin of the chalcedony veins described elsewhere in this paper.

DEVIL'S CORKSCREWS.

Among the interesting materials of the badland formations few have given rise to more speculations as to their origin than what are know as the Devil's Corkscrews of the Harrison beds. Devil's Corkscrews, or Daemonelix, as they are technically called, have been known by the early residents of northwestern Nebraska for many years but it was not until 1891 when Prof. Barbour made a collecting trip to Harrison and the Badlands that these strange objects were brought to the attention of scientific men. What they really represent or how they were formed is still a matter of conjecture. The more typical forms are upright tapering spirals and they twist to the right or to the left indiscriminately. The spiral sometimes encloses a cylindrical body known as the axis but it is more often without the axis. Sometimes the spiral ends abruptly below but more often there projects from the lower part one or two obliquely ascending bodies placed much as the rhizomes of certain plants. The size of the well developed form varies considerably. The height of the corkscrew portion often exceeds the height of a man while the rhizome portion is ordinarily about the size of one's body.

They are known to occur especially between the head waters of White and Niobrara rivers chiefly in Sioux County, Nebraska but extend westward as far as Lusk, Wyoming. The vertical range of strata carrying them is approximately 200 feet. Concerning their abundance Prof. Barbour says: "It intrudes itself upon you at every turn. On lands laid bare by erosion the half exposed and weathered tops of countless Daemonelix project. There they stand, bolt upright, till overthrown by the elements. We have picked our way through acres of these fallen spirals. In walls, bluffs, and buttes they are particularly accesible to the collector.

"It is apparent at a glance that they flourished in numbers of which one can form no conception. Growing closely packed side by side, they are often inextricably entangled and fused together. We have counted as many as twenty or thirty in the

space occupied by an ordinary dwelling house. We have often destroyed several while digging out one."*

Prof. Barbour who has given these interesting fossils most study considers them as representing some form of plant life and has apparently found much to corroborate this view. The surface of all forms shows as a mat or mass of fossil vegetable fiber much resembling "fine excelsior in a matrix of hydraulic cement." Microscopic study of thin sections shows abundant vegetable cells in the peripheral portion but the inner portion is usually structureless at least so far as plant development is concerned. Prof. Barbour has furthermore found that in going from lower to higher beds there is a gradual change in forms ranging from simple fibers and masses to those of ever increasing diversity and complexity (see Figure 9.)† This resembles

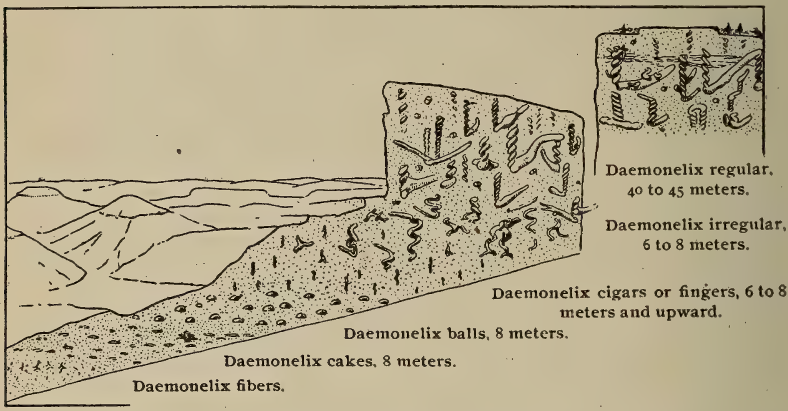

Figure 9—Diagrammatic section showing the relative positions of the several forms in the Daemonelix series. Barbour, 1896.

steps in phylogeny, but it is not at all sure that it really does represent phylogeny, for it may develop, as some believe, that the forms have only some indirect connection with organic life.

Some have considered that they represent low plant organisms such as algae, others that they may be remains of higher plants, in which all has decayed away except the cortical layer. Still others and these with much reason have considered them as casts of well preserved burrows of animals. Among the earliest

*Barbour, E. H. History of the Report and Progress in the Study of Daemonelix. Univ. Studies, (Neb). Vol. 2, 1897, pp. 81-124.

†Barbour, E. H. Nature, Structure, and Phylogeny of Daemonelix. Geol. Soc. Am., Bull., Vol. 8, 1897, pp. 305-314, pls. 31-39.

to suggest the latter idea were Dr. Theodore Fuchs of Germany and Prof. Cope. More recently Mr. O. A. Peterson has emphasized the latter view as a result of the finding of numerous fossils of burrowing rodents within the corkscrews.* In conclusion it may be said that no single suggestion as to the manner of origin seems as yet to cover all the varied features and uncertainty must needs linger until the discovery of some form or relationship that retains the unmistable key to the explanation.

MANNER OF DEPOSITION.

Geologists who first studied the badland formations of the western plains early formulated the theory that the deposits were collected by streams from the highlands of the Rocky Mountains and the Black Hills and were laid down as sediment in great fresh water lakes. These lakes were thought to have varied in position and extent in the different periods of time during which the several formations were being deposited. They were believed in general to have had their origin in certain structural changes, either a slight depression along the western side or the elevation of some drainage barrier on the east, and to have been obliterated by the development of new drainage channels accompanied possibly by general uplift, and by the progressive aridity of the climate.

More recently doubts began to be entertained as to the accuracy of this attractive lacustrine theory, more detailed study disclosing many facts at variance with the usual conditions of lake deposition, both with reference to the physical character of the deposits and to the nature, condition, and distribution of the fossil remains found in them. There now seems to be abundant evidence for the belief that the deposits were of combined lagoon, fluviatile, flood-plain, and possibly eolian origin instead of having been laid down over the bottoms of great and continuous bodies of standing water as was first supposed.

The lacustrine theory originated in the earlier accepted idea that all horizontally-bedded sedimentary rocks were deposited in bodies of comparatively still water, either marine, brackish, or fresh. It was believed that the fine-grained banded clays were deposited in the quiet deeper waters of the lake, that the sandstones and conglomerates were deposited along the

*Peterson, O. A. Description of New Rodents and Discussion of the Origin of Daemonelix. Carnegie Mus. Mem., Vol. 2, 1905, pp. 139-202, pls. 17-21.

shores and about the mouths of tributary streams, and that the wide distribution of the animals now found as fossils was accomplished by the drifting about in the lake of the decaying bodies washed down by the inflowing streams. The fossils obtained by the earlier students of the region showed a general lack of an aquatic fauna. As a result the idea developed that the waters of this great lake although receiving the drifting bodies of land animals were themselves of such a saline or alkaline nature that they were incapable of supporting life. It has more recently been shown that the waters were not only not saline, but that they were eminently fitted for the support of aquatic life and in fact in some localities did support such life, both plant and animal in great abundance.

The objections to the earlier views have been fully stated by Mr. W. B. Matthew, Prof. W. M. Davis, Mr. J. B. Hatcher, and others and are in brief as follows:*

Stratigraphic Evidence. First, the formations as now geographically determined if deposited in a lake would have demanded a body of water comparable in area to that of a great sea, and, during the long period required for the deposition of the sediments, should have developed important shore terraces. Such terraces, although diligently searched for, have not been observed.

Second, the lake must have been caused by a deformation of the earth's surface sufficiently rapid in its development to counteract the opposing channel cutting tendencies of the streams and of sufficient magnitude to overcome whatever aggrading influence the streams may have developed. There is no known evidence of any such basin-forming structure, the sediments lying on a surface which slopes gently and uniformly to the east.

Third, thin beds of sandstone and conglomerate occur in many places with the clays. These not infrequently show marked cross bedding and other swift current characters, and

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*1896. Gilbert, G. K., U. S. Geol. Surv., 17th Ann. pt. 2, pp. 557-601.
1897. Haworth, E., Kan. Univ. Geol. Surv., Vol. 2.
1899. Matthew, W. D., Am. Nat., Vol. 33, pp. 403-408.
1900. Davis, W. M., Proc. Am. Mus. Acad. Arts Sci., Vol. 35, pp. 345-373.
1901. Matthew, W. D., Am. Mus. Nat. Hist., Mem. Vol. 1, pp. 355-447.
1901. Johnson, W. D., U. S. G. S., 21st Ann. pt. 4, pp. 609-741.
1902. Hatcher, J. B., Proc. Am. Phil. Soc., Vol. 41, pp. 113-131.
1909. Osborn, H. F., U. S. G. S., Bull. 361.

may often be traced as greatly elongated lenses extending out toward or even far beyond the center of the region which the lake was supposed to have occupied. They are in general more abundant and coarser near the higher western border, but even here the fine clays often greatly predominate. Ordinarily coarse materials cannot be carried in quantity far within the borders of standing water nor can large deposits of fine clays be deposited near the margin. If the badland materials are lake deposits they indicate frequent and abnormal changes in the lake level. If they are river and lagoon deposits they indicate simply the change of course of a stream meandering on its flood plain. The trend of the coarser deposits is irregular, but there is a general convergence to the east and southeast so that in the area of the Big Badlands southeast of the Black Hills the sandstones and conglomerates are finer and less frequent and are generally wider and thicker than in the higher regions to the west and northwest. Mr. Hatcher indicates this in an excellent way by illustration from the Black Hills region.

"Taking the Protoceras sandstones as the most favorable example, owing to the greater extent to which they have been exposed by the subsequent erosion of the overlying sediments, they are seen to extend as a series of narrow elongated lenses from the Cheyenne and White River divide for several miles to the southward of the last-mentioned stream, where they pass beneath more recent deposits. Throughout their entire extent they exhibit frequent examples of cross-bedding, while the sands become finer and the channels fewer in number and broader and deeper as one goes southward toward and across the White River. That they have been removed by erosion over considerable areas lying between their present limits and the Black Hills is evident. At the summit of the Cheyenne and White River divide there are several of these sandstone lenses at approximately the same horizon. These bear many evidences of having been in the channels of small streams or rivers pertaining to a single drainage system, which had its source somewhere in the present region of the Black Hills and was tributary to a much larger river coming from the southwest. These sandstone lenses appear to converge and unite as one proceeds toward White River, like the tributaries of a stream."*

Fourth, the lowest beds in their contact with the Cretaceous and older rocks beneath show little or none of the depositional

*Proc. Am. Phil. Soc., Vol. 41, 1902. pp. 122-123.

conditions commonly resulting from an advancing lake margin such as a basal conglomerate or other water sorting features.

Paleontologic Evidence. First, the fauna of the clays is a land fauna. Remains of land animals as we know them and as the necessity of the case seems to demand are seldom or never found in abundance in open lake sediments. In the badland clays land animal remains are often excessively abundant and furthermore constitute the whole of the fauna. The clays are entirely free from fishes and such invertebrates and reptiles and mammals as might be expected to have lived in lake waters of that time. The sandstones likewise are deficient in aquatic life, but they do occasionally contain fishes and crocodiles and in one locality abundant unios (mussel shells) were found. Mr. J. B. Hatcher, in 1900 and 1901, in making a careful study of the Titanotherium and Oreodon beds found within the clays numerous thin lenticular limestones varying in thickness up to twelve inches or more which contained in abundance characteristic shallow water plants and mollusks such as live in fresh water swamps and small ponds and which could not have lived in the midst of a great lake. Furthermore, Hatcher at several places in the clays found marked evidence of land vegetation. He says, "At various localities in the Hat Creek basin, in Sioux County, Nebraska, I discovered remains of Hickoria and Celtis. These were found at various horizons from the Titanotherium beds to the very top of Loup Fork. And in South Dakota, some twelve miles north of White River, opposite the mouth of Corn Creek, I discovered the remains of no inconsiderable forest. Here in the upper Titanotherium beds and the lower Oreodon beds there occur actually by hundreds, the silicified stumps and partially decayed trunks of trees, weathering out of the fine clays of these deposits. It was noticeable that only the knots and lower stumps had been preserved. Nothing like complete trunks were to be observed, and the entire aspect was that of the remains of a dead and decayed forest on the margin of some stream, where only the less destructible knots and stumps would endure sufficiently long to be finally covered up and preserved. In this same region there were discernible certain strata which seemed to indicate that during the deposition of these beds there had been at several horizons an accumulation of vegetable mould or humus, and on Dry Creek, some five miles northeast of Chadron, in Dawes County, Nebraska, I observed near the base of the Oreodon beds a stratum of some two feet of dark colored

humus, clearly indicating that this region had not been occupied by a great lake while this stratum was being deposited."*

A further indication of the non-lacustrine condition, as pointed out by Matthew, is that many of the fossil bones seem to have been uncovered by sediments for a considerable time after the death of the animal. Many porous bones remain unfilled and many others are impregnated with silica rather than mud. The skeletons that remain complete are rare and are commonly much disarticulated. Often projecting portions are lacking, such as the head, the tail or fore limbs or lower part of hind limbs, or the lower jaw, or the ribs. These are the parts most likely to have been originally removed by the vicissitudes of the weather or by the feasting of preying beasts and birds.† Matthew thinks the climate was much as it is today and that wind action was a rather prominent factor in the distribution of the sand and clays and thus a potent factor in the covering up of the organic remains found in them.

Mr. Hatcher in his later investigation, although having no belief that the deposits were laid down in a large lake was nevertheless inclined to the idea that climatic conditions were considerably different from that of the same region today and that the surface of the country was possibly not unlike the present extensive marshy flood plains of the upper Amazon, Oronoco, and Paraguay of South America.

Mr. Gilbert first suggested in 1896 the probable fluviatile origin of the deposits, particularly for those in eastern Colorado. Prof. Davis in 1900 indicated that the capacity of rivers to form extensive deposits of fine texture and even stratification was too frequently underrated and, enlarging upon Gilbert's earlier suggestion, directed attention to the possibility of the Great Plains Tertiary deposits constituting a great piedmont plain of prevailing fluviatile origin. Mr. Darton, 1905, considers that during a long period streams of moderate declivity flowed from the west across the region and that these streams with frequently varying channels and extensive local lakes, due to damming and the sluggish flow of the water, laid down the wide-spread mantle of Oligocene deposits, the Brule formation being apparently deposited under conditions in which the currents were weaker and the local lakes and slackwater overflows more ex-

*Am. Phil. Soc. Proc., Vol. 41, 1902, pp. 126-127.

†Matthew, W. D. Fossil Mammals of Northeastern Colorado. Am. Mus. Nat. Hist., Mem. Vol. 2, pt. 7, 1901, pp. 359-368. (Condition of deposition.)

tensive. The Arikaree he considers as a flat alluvial fan of wonderful extent probably spread out over the Plains region by streams aided to a minor extent by winds.

Prof. Osborn has quite recently summed up all of the evidence and states that the present opinion appears to be as follows:

"The topography of the Plains Region was in Oligocene to lower Pleistocene time, as now, level or gently undulating, not mountainous. On the gentle eastward slopes of the Rocky Mountains and the Black Hills were borne broad streams with varying channels, backwaters, and lagoons, sometimes spreading into shallow lakes, but never into vast fresh-water sheets. Savannas were interspersed by grass-covered pampas, traversed by broad, meandering rivers which frequently changed their channels. This accounts for the presence of true conglomerates, true sandstones, calcareous grits, gypsum, fine clays, fullers' earth, fine loess, eolian sands, and even, far out on the plains of Nebraska and Kansas (and South Dakota) widespread deposits of volcanic dust, wind borne from distant craters in the mountains to the west and southwest. In the early Oligocene and Miocene the deposits were chiefly fluviatile or river sandstones and conglomerates interspersed with fine flood plain or overflow deposits, perhaps locally lacustrine, partly of volcanic ashes. As the dessication or aridity of the country increased, the mountain-fed rivers became smaller and narrower, while the eolian or loess deposits apparently became more common, beginning in the middle Miocene. The deposits also became more and more restricted in extent as the Miocene advanced. The newer river channels cut down into the older series, thus using the erosion materials a second time."*

From the above it may be seen that in large measure the determination of this question of manner of deposition, like so many other nature puzzles, seems to have waited merely more refined investigation. This has now been supplied with some degree of fulness by the various field parties, and while there are yet doubts as to the relative importance of certain features and much work still to be done, Prof. Osborn's summary so far as present knowledge is concerned may be taken as adequate and satisfactory.

SOURCE OF MATERIALS

The immediate source of the badland deposits is not definitely known. The material was evidently derived from

*U. S. Geol. Surv., Bull. 361, p. 28.

land areas to the west, southwest, and northwest of their present position, but from what earlier formations or from what kinds of rock, except for certain local areas, has not been positively determined.

The coarser materials, particularly the heavy conglomerates and coarser sandstones between Rapid City and Buffalo Gap, were clearly derived from the older rocks of the central Black Hills, particularly the quartzites, granites, basic igneous rocks, and vein quartz.

Concerning the finer deposits Newton, in his report on the geology of the Black Hills, 1880, says: "It is worthy of remark that while the deposits of the Cretaceous, from the demolition of which the White River Tertiaries were evidently formed are dark carbonaceous clays or shales, the latter are notable for their light color. This is probably due to the making over of the sediment in shallow water, whereby the carbonaceous matter was oxidized, leaving the accumulation nearly white in color." Hatcher, in his paper on the Titanotherium beds, 1893, states that these beds were probably derived from two sources, namely, from the Cretaceous clays and shales and from the kaolinization of granitic feldspars. The sandstones he says are composed of quartz, feldspar, and mica, and are evidently of granitic origin. Matthew, 1901, considers that a considerable part of the materials was perhaps derived from the Niobrara chalk.

Accepting the present generally accepted view as to the manner of deposition of these deposits, a discussion of which has just been given it is clear that there would be abundant opportunity for a thorough distributing and commingling of material from many sources and for oxidation to the fullest extent as suggested by Newton. However that the Cretaceous rocks were the main contributors may well need further proof in view of the fact that many areas showing typical light colored deposits lie far within the Cretaceous outcrops as we now know them and in view of the further fact that the Tertiary deposits were certainly at one time distributed over a far wider region than was earlier supposed.

GEOLOGIC HISTORY

The rocks of the earth's crust retain to a marked extent a record of their history. Sometimes this is indicated by composition, sometimes by manner of erosion, sometimes by relation to one another, sometimes by fossil contents, et cetera. Often several such characters are available in the same formation. In

such cases the history may be unraveled with much fulness.

A detailed history of the Tertiary of the Black Hills region may not be entered upon here, but a brief review of the general physical changes is desirable in order that the setting of conditions and activities discussed on various pages elsewhere in this paper may be better understood.

Preceding the deposition of the Tertiary rocks, that is during the Cretaceous period, the Black Hills region had for a long time been surrounded and largely if not wholly covered by a great sea. In this sea countless marine organisms flourished and died. The sea from time to time, and particularly near the close of the period, tended through a brackish to a fresh water nature. Approximately coincident with the full development of fresh water conditions the Black Hills region was subjected to a great disturbance, profound elevation took place and a more active erosion was inaugurated. The waste products of this earliest Tertiary erosion (Eocene) have not been preserved but the trenched Cretaceous-covered surfaces, later filled with Oligocene materials, indicate in a way the passing events.

The Oligocene streams were in general of moderate declivity. Away from the central part of the uplift swampy conditions for a time were prominent, and the streams were evidently sluggish and muddy. These slow moving streams by meandering developed vast flood plains across which they shifted their lazy way and deposited and redeposited the debris obtained from the higher lands to the west. Following the Oligocene the main Black Hills uplift was raised some hundreds of feet higher and erosion was correspondingly quickened, but the general history continued much as before.

The climate for a considerable time in the history of deposition of the badland formations seems to have been moist to a marked degree. Later a more arid condition prevailed. During this later time transportation and deposition by wind seems to have become a feature of some importance. Throughout it all animal life was prodigious and varied and the bones of these bygone creatures mingled with the sediments in countless numbers.

The great disturbance near the beginning of the Tertiary resulting in the pronounced doming of the Black Hills region and the development of the general structure as we now know it was accompanied by profound intrusion in the Northern Hills and in the Rocky Mountains to the west and southwest. Within the Rockies some of this igneous material connecting

with the throats of vigorous volcanoes was from time to time hurled high above the surface. Here favorable winds, catching up the finely divided fragments, bore them far to the eastward and there gently dropped them as thin widespread ashen blankets to become an integral and interesting portion of the general badland deposits. Subsequent to the Miocene the history of the badland formations of the Black Hills region is largely one of rapid weathering and vigorous erosion.

PHYSIOGRAPHIC DEVELOPMENT

The badlands of the Black Hills region are the result of erosion, controlled in part by climatic conditions and in part by the stratigraphic and lithologic nature of the deposits. There is a too frequent lack of appreciation of the work of common disintegrating and carrying agents and many an individual speculates upon the mighty upheavals and the terrible volcanic forces that to him have produced the wonderful ruggedness of the badlands, when the real work, so far at least as immediate topography is concerned, wholly apart from the forces of vulcanism, have been performed under a kindly sun and through benevolent combination by ordinary winds and frosts and rains, and to a lesser degree by plants and animals. What the earliest beginings may have been is not known. Suffice it to say that then, as now, the sun shone, the winds blew, and the rains came, and such irregularities as may have existed influenced in some degree the earliest run off. Season by season the elements weakened the uplifted sediments, and little by little the growing streams etched their way into the yielding surface. In time lateral tributaries pushed their way into the interstream areas and these tributaries in turn developed smaller branches, the series continuing with ever increasing complexity to the delicate etching at the very top of the highest levels. All the important streams, the Little Missouri, the Grand, the Moreau, the Cheyenne, and the Belle Fourche, the Bad, and the White rivers, give indications of an eventful history, but for this there is little opportunity for discussion here. Cheyenne river and White river are the chief factors today in the production and continuation of the badland features, and of these, White river clings most closely to its task. The Cheyenne has already cleared its valley of the badland deposits except in the important locality southeast of the Black Hills and in the western Pine Ridge area beyond the headwaters of White river, and

even in these areas the main stream has cut entirely through the formations and in most places deeply into the underlying black Cretaceous shales. White river, on the other hand, for more than fifty miles of its middle course, meanders across a wide alluvial bottom, underlain by badland sediments, while its many branched head and all of the larger tributaries from the south and many from the north continue to gnaw vigorously into deposits that retain much of their original thickness.

Among the innumerable tributaries within the badlands proper, few are of great length, but many are of note in the physiography of the region, in the history of early day travel, and in the yielding of important specimens to the fossil hunter. Of those leading from the Badlands to the Cheyenne river, the following in Pennington County are important and often referred to in the scientific literature: Bull creek, Crooked creek, Sage creek, Hay creek, Bear creek, Spring creek, Indian creek, Little Corral draw, Big Corral draw, Quinn draw, and Cedar draw. Nearer the head of the river are Hat creek, Old Woman creek, Lance creek, and others. Three streams rise in the eastern part of Pennington County and, flowing eastward, form the head of Bad river. These are Cottonwood, White Water, and Buffalo creeks. The White river tributaries from the north are short, and with the exception of Cain creek, Cottonwood creek, and Pass creek, rising near the heart of the Big Badlands, need no further mention here. The White river tributaries on the south are numerous, and of considerable size. The best known ones within the area considered, all within the Pine Ridge Indian reservation, are: Pass creek, Eagle Nest creek, Bear in the Ledge creek, Corn creek, Pumpkin creek, Yellow Medicine creek, Medicine Root creek, Porcupine creek, Wounded Knee creek, and White Clay creek. Little White river is the most important of all the streams flowing into White river, but it lies just outside the area represented on the map. Certain geological and paleontological studies made in the valley near Rosebud are referred to elsewhere because of their bearing on studies made in the area covered by this paper, but aside from this, Little White river need not receive our further attention.

In addition to the streams certain features need mention because of their commanding position. These are Pine Ridge, Porcupine Butte, Eagle Nest Butte, Sheep Mountain, and "The Wall," the latter being more fully designated by the various local names: Sage creek wall, White Water wall, Big Foot

Photograph by O'Harra, 1909.

Figure 1. White River at wagon bridge near Interior.

Photograph by O'Harra, 1899.

Figure 2. Cheyenne River near mouth of Sage Creek.

Photograph by O'Harra, 1909.

Figure 1. Sun-cracked surface of an alluvial flat showing loosening and curling of the drying mud.

Photograph by O'Harra, 1909.

Figure 2. Spongy surface of Titanotherium clay showing ease of disintegration.

Photograph by O'Harra, 1909.

A dry ravine in alluvial deposit cut into box-shape by rapid run off. Near Interior.

Photograph by O'Harra, 1909.

Figure 1. Clay balls in bed of little ravine near Big Foot Pass.

Photograph by O'Harra, 1899.

Figure 2. Conglomerate dike in valley of Indian Creek.

wall, et cetera. In addition to these, the following passes or natural roadways, well known to all the travelers within the Big Badlands, are of historic importance and of physiographic significance: Sage Creek pass, Big Foot pass, Cedar pass, Chamberlain pass, et cetera.

Less noted in the literature, but of much importance, are the numerous mesas or tables. They stand at various heights up to three hundred feet or more above the basins or valleys. Some of these are of large size and those east of the Cheyenne river have been given individual names by the people who have settled upon them. The larger ones are Sheep Mountain table, about six miles south-southwest of Scenic; Hart table, between Indian creek and Spring creek; Kuba table, between Spring creek and Bear creek; Seventy-one table, between Bear creek and Hay creek; Quinn table, between Hay creek and Sage creek; Crooked Creek table, between Sage creek and and Bull creek; Lake Flat, between Bull creek and the headwaters of Cottonwood creek; White River table, at head of Quinn draw. The last named lies within the Pine Ridge Indian reservation and is of historic interest in that it was used as a fortress by the Indians during the Indian outbreak of 1891.

The chief factors in badland development are these: First, a climate with a low rainfall more or less concentrated into heavy showers; second, scarcity of deep rooted vegetation; third, slightly consolidated nearly homogenous fine-grained sediments lying at a considerable height above the main drainage channels, the occasional hard layers or beds that may be present being thin and in horizontal position. All of these favor rapid, steep, and diversified sculpturing. As already stated, the White and the Cheyenne rivers, not far separated from each other, serve as the main drainage channels for the Badlands and, having cut far below the topmost mesas or tables, afford abundant opportunity for rapid run off. The vegetation as we know is scanty. Rich, short grasses are abundant over large areas, but these have not sufficient root-strength to prevent cutting. The gnarled cedars of the higher points also lack such strength, for even these often wage a losing fight and especially in the elongating gulches and on the narrowing tables they progress toward inevitable destruction.

The rock material is largely an excessively fine clay, not thoroughly indurated, sometimes massive, sometimes laminated. Sandstones occur locally in some abundance, especially in the upper beds, but never of great thickness and seldom of much

lateral extent. Concretions are common and these as well as the sandstones accentuate the irregularity of erosion. The bare clay slopes under the influence of occasional rains and the beating suns, generally show a spongy surface, the loosening porous clay often extending to a depth of several inches. This feature is common on the sloping surface of the Oreodon beds and is especially characteristic of the rounded hillocks of the Titanotherium beds (see Plate 17). This preliminary loosening of the clay, explains perhaps more than any other one feature, the surpassing ease with which the countless tiny channels are formed and how it is that the streams become turbid with every passing shower.

Any hard layer that may be present tends to resist erosion and this at once initiates surface irregularities. The unconsolidated clays being more rapidly removed, the harder stratum soon stands out in distinct relief and later by undercutting, a precipice develops. Joints often accelerate the erosion along certain vertical planes and the result is the development sometimes of cave-like excavations and sometimes of columnar masses. Columns are likely to develop also in connection with hard strata made up of concretionary masses. They are especially abundant in the Protoceras beds, where concretionary masses and jointed sandstones are both abundant.

Generally the transportation lags perceptibly behind the disintegration and as a consequence a thin fan of sediment clings to the base of every pillar, mound or table. The full extent of these alluvial fans is often not fully discerned. Being formed by the conjoint action of many little streams and made up of excessively fine sediment, their surface slope is low and one readily confuses the alluvial materials with the undisturbed beds on which they lie. As may be readily inferred, there is much transient carrying of sediments and much meandering of maturer streams. A single season or even a single freshet often makes important changes in a stream's position and there is decided tendency in the medium sized streams to quickly develop box-like trenches (see Plate 18). Cheyenne river and White river are active throughout the year, and during the rainy season they flow in large volume, but the tributary streams coming from the badlands are dry much of the time. Some are able to struggle along in continuous flow for a little while after the rainy season, but later in most of them little is left but dusty sands and stingy pools of water, the latter clear if strongly alkaline, otherwise turbid to the consistency of mud porridge.

ECONOMIC MINERAL PRODUCTS

The badland formations have not as yet attracted any particular attention as sources of mineral wealth. This is due partly to the absence of mineral variety and partly to the lack of local demand for such materials as are available.

Building Stone. Sandstones and limestones occur, but they seldom meet the requirement of a high grade building stone. They are nearly always thin-bedded and generally more or less argillaceous. The sandstones are often of coarse or irregular texture and poorly cemented. In view of the fact that excellent building stone is extensively quarried not far away, near and within the Black Hills proper, it would seem that the badland stone gives little promise of utilization, except in occasional places as a local convenience.

Clays. Clays are in unlimited abundance and of considerable variety. Analysis show that they could be utilized in various ways, particularly in the manufacture of brick and cement.

Fullers' Earth. Some of the badland clays, especially those of the Titanotherium beds, have the property of decolorizing or clarifying oils, hence are known as fullers' earth. Many places disclose clay of this character and from two localities, namely, near Argyle anr near Fairburn, test shipments have been made. It seems probable that by careful sampling, large quantities of good material could be obtained. Prof. Heinrich Ries of Cornell University, gives the following analyses for the localities mentioned, analyses 1, 2, 3, 6 being of material from near

Analyses of Fullers' Earth From the Titanotherium Beds.

Constituent.	1	2	3
	Per cent	Per cent	Per cent
Silica (SiO_2)	68.23	60.16	56.18
Alumina (Al_2O_3)	14.93	10.38	23.23
Ferrous oxide (FeO)	3.15	14.87	a 1.26
Lime (CaO)	2.93	4.96	5.88
Magnesia (MgO)	0.87	1.71	3.29
Loss on ignition	6.20	7.20	b 11.45
Total	96.31	99.28	101.29

a Fe_2O_3 b H_2O.

Constituent.	4	5	6
	Per cent.	Per cent.	Per cent.
Silica (SiO_2)	55.45	57.00	58.72
Alumina (Al_2O_3)	18.58	17.37	16.90
Ferrous oxide (FeO)	3.82	2.63	4.00
Lime (CaO)	3.40	3.00	4.06
Magnesia (MgO)	3.50	3.03	2.56
Loss on ignition	8.80	9.50	8.10
Volatile	5.35	5.85	....
Alkali	....	....	2.11
Moisture	....	....	2.30
Total	98.90	98.35	98.45

Fairburn, and analyses 4 and 5 of material from near Argyle*

Volcanic Ash. Volcanic ash has been mentioned in the description of the various formations. It is made up of minute fragments of natural glass. The ash, if its individual particles are of uniform size and have sharp cutting edges, has economic value as a polishing powder or in the prepared state as an important constituent of abrasive soaps. Several deposits of this character have been observed within the Black Hills region, the best known ones being near Oelrich and at the fullers' earth locality near Argyle.

Bone Phosphate. The fossil bones found in the badland deposits, like the bones of present day animals, generally contain much phosphate. There is little reason, however, to believe that the phosphate can be utilized commercially. Men speak of the abundance of the fossil bones, but it should be stated that this is more particularly from the viewpoint of the scientist interested in their educational value rather than that of the manufacturerer of commercial bone products. There seems never to have been any very great tendency for the phosphate to leach out from the bones and concentrate into beds. In a few instances the matrix enclosing bone material has been analyzed, but so far as I am informed, the amount of contained phosphate has been small. Mr. D. D. Owen of the Owen Geological Survey, in an analysis of the matrix of the skull of an Oreodon gives the phosphoric acid as 1.80 per cent, and for the matrix

*Ries, Heinrich. The Fullers' Earth of South Dakota. Trans. Am. Inst. Min. Eng., Vol. 27, 1897, pp. 333-335.

Photograph by O'Harra, 1909.

Upper portion of Cedar Pass near Interior.

Photograph by O'Harra, 1909.

Figure 1. The Great Wall between Cedar Pass and Big Foot Pass. Protoceras Beds above. Oreodon Beds below.

Photograph by O'Harra, 1909.

Figure 2. The Great Wall between Cedar Pass and Big Foot Pass. Protoceras Beds above. Oreodon Beds below

Photograph by O'Harra, 1909.

Figure 3. General view showing contact of the Titanotherium Beds with the overlying Oreodon Beds. Near Big Foot Pass. The highest Titanotherium Beds here are red.

Pine Ridge escarpment at the Nebraska-Wyoming state line. The high cliffs are of Arikaree sandstone. Brule clays below. Darton, U. S. Geol. Surv., Prof. Paper, No. 32.

Ricard Art Co., Quinn, S. D.

Figure 1. Cattle descending from grass-covered table land to grass-covered valley below.

McNamara's Book Store, Rapid City.

Figure 2. The 6 L Ranch near Imlay showing success in soil cultivation.

of the scapula of a "Palaeotherium" as 1.90 per cent.* For those interested in the chemical nature of the bones, I give the following careful analyses made many years ago by Dr. Francis V. Greene from material collected by the Owen Survey and published in the American Journal of Science, 1853.† Others by D. D. Owen are given in the Owen Survey Report, 1852.

Analyses of Badland Fossils

Constituent.	1	2	3	4
	Per cent	Per cent	Per cent	Per cent
Phosphoric Acid (P_2O_5)	33.98	39.15	35.97	31.19
Silica (SiO_2)	0.09	0.48	0.79	0.26
Ferric Oxide (Fe_2O_3	1.77	....	....	....
Fluorine (F)	0.40	0.04	1.42	2.46
Magnesia (MgO)	0.33	0.22	0.53	1.14
Lime (CaO)	49.77	51.80	51.23	50.83
Potash (K_2O)	0.31	0.24	0.23	0.28
Soda (Na_2O)	1.13	1.28	0.75	1.57
Baryta (BaO)	0 36	....	....	1.10
Chlorine (Cl)	....	....	....	0.02
Sulphuric Anhydride (SO_3)	0.88	1.01	1.51	2.19
Carbonic Acid (CO_2)	4.08	3.17	2.83	2.77
Water (H_2O)	2,04	0.62	2.10	1.97
Organic Matter	5.67	2.54	2.66	4.09
Total	100.81	100.55	100.02	99.87

In the above analyses, No. 1 is that of a Titanothere bone, No. 2 of a Titanothere tooth (enamel), No. 3 of a Titanothere tooth (dentine), No. 4 of an Archaeotherium (Elotherium) bone.

Gold. Gold is reported to be found occasionally in the gravels of the Big Badlands. It occurs in appreciable quantity only in placer form, and how extensively it is distributed through the formation is not known. Its presence seems to be limited

*Owen, D. D. Report on a Geological Survey of Wisconsin, Iowa, and Minnesota; and Incidentally of a Portion of Nebraska Territory. Philadelphia, 1852, p. 606.

†I am indebted to Prof. M. F. Coolbaugh of the Department of Chemistry in the School of Mines, for reviewing the original analyses and changing them to harmonize with present day usage.

to favorable places, where there has been considerable opportunity for recent concentration. A sample from the northwest corner of section 18, township 2 south, range 15 east, on North Sage creek recently assayed at the School of Mines, showed a value of forty cents a ton, equivalent to approximately forty-nine cents a cubic yard. This in itself might seem to indicate opportunity for fair return for labor, but the concentrated gravels are not plentiful and through much of the year favorable water supply is lacking.

FOSSILS

Fossils as generally understood are the parts of animals and plants living before the present era that have been buried in the rocks and preserved by natural causes. The manner and degree of preservation vary greatly. The essential thing is the sealing up of the remains in the rocks so that destruction and decay may be prevented. Animals such as the ice-entombed mammals of Siberia, or the amber enclosed insects of the Baltic, are practically perfect as the day they were buried, but they are exceptional. Generally only the hard parts, such as bones or teeth, or shells remain. Not infrequently these are replaced, particle by particle by new mineral matter of some kind, particularly silica or pyrite, then they become petrifactions. Sometimes only the form or the impression of the original parts are preserved, hence the terms molds and casts. Occasionally the relics are limited to footprints, or trails, or burrows, or borings, or eggs.

Animals living in the water or frequenting marshy places for food and drink are more easily and more quickly buried beneath sediments, hence their fossils are usually more abundant. The bodies of dry land animals are subjected to the vicissitudes of sun and rain and wind, and frost, and are often feasted upon by scavenger birds and beasts and insects. Furthermore their burial is commonly brought about only during flood season. All of these tend to the destruction or dismemberment of the various parts. Again, even if once nicely buried, they may later be obliterated by metamorphism or be destroyed by disintegrating and denuding agencies. As a result of all this, the history of certain groups of animals is meagre in the extreme and doubtless hordes of species have left no worthy evidence of their ever having lived.

EXTINCTION, EVOLUTION, MIGRATION

In the study of the life history of the fossil organisms puzzling questions are continually arising for urgent answer.

One of the most important among these is the cause of extinction* Why was it that animal groups battling for position in life's long race and gaining for a time supremacy in their field, were in turn obliterated by the contending forces of their environment?

In attempting an answer it should first be stated that the term may not always be fully understood since extinction is sometimes apparent rather than real. Often one species dwindles out of existence into another and occasionally, as in the horse, camel and rhinoceros, and other families, the consecutive changes may be traced through a long continued series of replacements by the process of gradual development. Again the seeming extinction may be only a migration from the locality in question and in the new environment activity may continue as favorable as before.

In case of actual extinction it is often not possible to ascertain the immediate conditions. Sometimes the extinction is due wholly to causes external to the animals themselves, such as unfavorable climate, alteration of food supply, ravages of disease, encroachment of hostile species, insect pests, et cetera. Again extinction may be due largely to lack of internal adaptation and adaptability, for example, the teeth may be fitted for too little variation of food, or the brain may be deficient in size or quality so that the animal lacks resourcefulness, alertness, and enterprise.

All animal groups pass through innumerable vicissitudes, the immediate effects of which so far as concerns individuals are often harmful, although the result upon the group may be beneficial. Too great repetition or abnormal character of the oppressive conditions tend, always, to deterioration and may in the end lead to obliteration. Of the animals referred to in this paper, several groups are wholly extinct, no relatives of any reasonable nearness being found living today. Notable among such are the Titanotheres and the Oreodons. Reference to the extinction or relationship of others is given in connection with their description.

Concerning migration little may be said. Suffice it to state that at certain times new forms appeared from outside regions and broad comprehensive study with reference to both the new and the old world has revealed fairly definite physiographic con-

*For an excellent recent discussion of this subject see Osborn, H. F. The Causes of Extinction of Mammalia. Am. Nat. Vol. 40, 1906, pp. 769-795, and pp. 829-859.

ditions attendant upon such migration. Mammalian life since the beginning of Tertiary time has passed through various faunal phases, the nature of which has been controlled to no little degree by the presence or absence of opportunity for faunal interchange between the several continents.* The accompanying Figure 10, adapted from Matthew, is an attempt to indicate

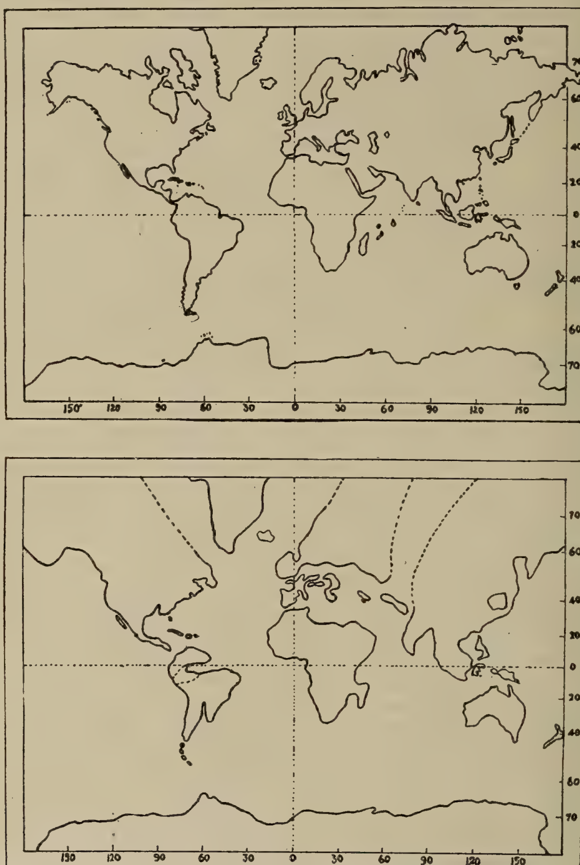

Fig. 10—Hypothetical Continental outlines—Middle Oligocene. Matthew, 1906

in a general way the relations of all the continents during the Middle Oligocene time†

*For a brief, important, recent statement of the conditions see Osborn's "Correlation of the Cenozoic Through Its Mammalian Life," Journ. of Geol., Vol. 18, 1910, pp. 201-215.

†Matthew, W. D. Hypothetical Outlines of the Continents in Tertiary Times. Am. Mus. Nat. Hist., Bull. Vol. 22, 1906, pp. 353-383.

COLLECTING AND MOUNTING

In the earliest explorations in the Badlands little careful effort was made to secure complete skeletons, the explorer apparently contenting himself with securing only the better heads or other fragments lying on or near the surface. Later extensive digging was resorted to, but for some years this was done in a crude way. The bones are generaly more or less broken and disarticulated and when once the fragments become separated the proper assembling of the pieces again becomes a difficult task. In course of time a method of bandaging developed. Now the fragments while being excavated are fastened together by means of burlap or other coarse, loose-woven cloth laid on with flour paste, plaster of paris, et cetera. Soft bones are treated with some preparation of shellac or gum to harden them for transportation. Exact location of the skeleton and every bone in the skeleton is of the greatest importance. A knowledge of the stratigraphical horizon is essential to determining much of the relationship and life history of the animal and the proper location of each bone with reference to neighboring bones of the same excavation may serve greatly in the mounting of the restored skeleton. Sketches and photographs of the excavation as the work progresses, together with careful labeling of the various pieces aid materially in this and are often utilized.

Reaching the preparator's laboratory the bandages are carefully removed, all useless matrix cleared away and the bone fragments assembled and cemented together. Injured bones are then repaired and missing bones reproduced in some suitable artificial preparation. The mounting is often facilitated by study of the living relatives of the fossil form. Where there is no living animal nearly related, recourse is had to the studies of the rugosities of the bones where the main muscles were attached in life, the facettes of the joints and the general shape and character of the various bones.

All this work, if properly done, requires much patience and skill in manipulation as well as intelligent insight into the general nature of the animal to be mounted. Many weeks or months may be required in the laboratory work alone, the expense of preparation usually far exceeding the time and money spent in collecting the specimens in the field. It may be readily inferred that the money value, to say nothing of the educational

importance of the completed skeleton, particularly if it is the type specimen of a new species, is often very great.*

THE CLASSIFICATION AND NAMING OF EXTINCT ANIMALS.

The naming of animals, both living and extinct is closely interwoven with their classification. Classification is a process of comparison. Its object is to bring together the like forms and to separate the unlike. This is best accomplished by comparing the various characters which are the most constant. The natural result is the arrangement of groups within groups in a continuous manner, the various groups being given particular names, as, Kingdom, Subkingdom, Class, Order, Family, Genus, Species et cetera. The scientific name by which any animal is indicated is formed by combining the generic and specific names much as we combine our own family and Christian name except that in the scientific nomenclature the specific term comes last. To illustrate: the scientific name of the domestic dog is *Canis familiaris* Linnaeus, *Canis* being the name of the genus and *familiaris* the name of the species. The third non-italicized portion is strictly a part of the name although this really refers only to the naturalist who first carefully described and properly named the creature. It is often omitted, especially in the case of fairly common or well known animals or where there is no mistaking the individual who gave the name. In scientific literature, however, and particularly in paleontology where, on account of imperfect material, there is liability of error in determination this is usually given as it not infrequently becomes essential for clearness in referring to the species. Omitting it from the name for the time-being, the complete classification of the dog may be represented as follows:

Kingdom, *Animalia.*
  Sub-kingdom, *Vertebrata.*
    Class,*Mammalia.*
      Order, *Carnivora.*
        Family, *Canidae.*
          Genus, *Canis.*
            Species, *Familiaris.*
              Variety, *"Shepherd."*
                Individual, *"Shep."*

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*The following recent publication will be found of much help by those desiring information as to details of preparation: Hermann, A. Modern Laboratory Methods in Vertebrate Paleontology. Am. Mus. Nat. Hist., Bull. Vol. 26, 1909, pp. 283-331.

Continuing the illustration the scientific name of the tiger is *Felis tigris* Linnaeus; of the Ox, *Bos taurus* Linnaeus; of man, *Homo sapiens* Linnaeus. These names are simple enough when once understood and indeed many names we now look upon as common have been transferred bodily from the scientific generic nomenclature, as for example, rhinoceros, hippopotamus, bison, and mastodon.

It is well known that the common names by which animals now living are designated are often not sufficiently accurate. The name in order to be properly useful must be sufficiently distinctive to indicate clearly the animal to which reference is made. For example, there are five existing species of rhinoceroses, the clear definition of which by common names is perhaps difficult enough, to say nothing of the score or more of fossil forms besides a still larger number of extinct animals closely allied to the rhinoceroses and falling under the general Class, Rhincerotoidea. Again sometimes the common name is deceptive. For example the well known "pronghorn" antelope, *Antilocapra americana,* of our western plains is really not an antelope at all.* True antelopes at the present day inhabit only Europe, Asia, and Africa. They include many species the better known ones being designated in common speech as hartebeests, gnus, elands, gazelles, klipspringers, gemsbocks, springboks, waterbucks, duickerboks, saigas, etc. Several of these are subdivided. For example the duickerboks alone are credited with thirty eight species. If, therefore, we are going to name animals in conformity with their recognized distinctions, and for clearness of conception there is generally no alternative, then the various duickerbok species must each be given a name—thirty eight in all. Thus antelope being in reality a misnomer here in this country and losing much of its distinctive significance even in the old world, becomes little more than a loose expression for a great group of animals, some of them no larger than a jack-rabbit, and others comparable in size to a horse.

Generally in designating the species, the words of the

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*For a recent discussion of the classification of the antelope the reader is referred to the following papers:

Beddard, F. E. Mammalia. 1902.

Grant, Madison. The Origin and Relationship of the Large Mammals of North America. N. Y. Zoological Society. Eighth Ann. Rept. 1904, pp. 26-27.

Lyon, M. W. Remarks on the Horns and on the Systematic Position of the American Antelope. Proc. U. S. Nat. Mus., Vol. 34, pp. 393-402.

scientific name refer to some important character, or they express some relationship or resemblance, or indicate some fact of distribution or discovery. Sometimes the meaning is obscure in which case it may be necessary to consult the work of the original author for the interpretation. Often, however, the name needs little explanation other than that given by a good comprehensive dictionary.

The generic names are usually of classic origin, most of them being Latinized forms of Greek names. They may be either simple or compound words and they often have modifying or descriptive prefixes or suffixes. The specific names show a somewhat wider latitude of origin than the generic names. Sometimes they are geographical, sometimes personal, oftentimes descriptive. The following names of badland fossils may serve to illustrate the principle: *Procamelus occidentalis* Leidy, an ancestral camel of the new world, described by Leidy; *Magacerops brachycephalus* Osborn, a short headed animal with a great-horned appearance, described by Osborn; *Neohipparion whitneyi* Gidley, a new world, small horse described by Gidley and named in honor of W. C. Whitney, who, by generous financial aid, greatly advanced the study of fossil horses; *Protoceras celer* Marsh, a fleet-footed first-horned animal described by Marsh; *Protosorex crassus* Scott, a large sized primitive shrew, described by Scott.

It would lead us too far away from the main purpose of this paper to go into the full details of this nomenclature. One additional feature, however, deserves notice in view of its not infrequent perplexity. The individual who first describes a new species is supposed to give it a name which must not conflict with any name used previously for another species. According to the rules governing the matter the name by reason of its priority can not be changed subsequently except for cause. Often in paleontological work where poor or insufficient or aberrant material has been first studied later discoveries have shown errors of description or improper identification in which case a new name may become necessary. The new name, if properly given becomes the accepted name while the old name is referred to as a synonym. In not a few cases there are several synonyms and not infrequently it is a matter of some conjecture as to just which is the most appropriate under the circumstances.

With rare exceptions the animal life of the badland formations of the Black Hills region is restricted to the Vertebrata—the back-boned animals. Aside from turtles of which there are

many, and a few crocodiles, lizards, and birds eggs, all of the fossil remains of the vertebrates thus far found within the area belong to the great class "Mammalia". The term "Mammalia" includes all hair-clad, vertebrated animals, the females of which are provided with glands for secreting milk for the early nourishment of the offspring. They are the highest of the vertebrates, possessing that happy combination of anatomical and physiological simplicity and complexity tending toward highest efficiency as organisms. They are not only the most important animals of today, but they have been the rulers of the animal world since early Tertiary time. Continuing back in geological history with ever increasing simplicity toward a generalized, omnivorous, allotherian ancestry they may be traced with certainty to Triassic time. Since their beginning multitudinous changes have taken place in the structure and activity of the many species that have originated, developed and died and, as a result, the expression of relationship must often be indefinite or uncertain.

Following the custom of many authors two great sub-classes of the Mammalia may be recognized, namely, the Prototheria or primitive mammals and the Eutheria or perfect mammals. The Prototherian mammals are restricted to very simple forms such as the Echidna (Australian Ant-eater) and the Ornithorynchus (Duck-billed Platypus) which lay large yolked eggs much after the fashion of reptiles and birds. The Prototheria are not represented in the Black Hills region either living or fossil, hence need no further consideration in this paper.

The Eutheria unlike the Prototheria include a vast assemblage of forms of all sorts of perfection of development from the lowly marsupials or pouch-bearing animals (sometimes classed as Metatheria) to man. These are grouped somewhat differently by different authors but all of the fossil forms obtained from the region under discussion in this paper fall naturally into four main divisions, namely, the Insectivora, the Carnivora, the Rodentia, and the Ungulata (hoofed mammals), the Ungulata (Herbivora) being represented by two orders, the Perissodactyla and the Artiodactyla.*

The Insectivores include moles, hedgehogs, shrews and other small animals of antiquated structure. They are gener-

*The Proboscidea are represented by two broken teeth found in 1906 in the lower part of the Upper Harrison beds near Agate, Sioux County, Nebraska. These were described by Mr. Harold J. Cook in the Am. Journ. Sci. vol. 28, 1909, pp. 183-184 under the name *Gomphotherium conodon*.

ally plantigrade (walking upon the sole of the foot), the snout is often prolonged into a short proboscis, and their chief food is insects. The Carnivores include animals whose chief food is flesh. They may be terrestrial, arboreal, or aquatic. They have a simple stomach, a well developed brain, toes provided usually with long, sharp claws, and generally they have a body capable of much agility in the capture of prey. They walk either upon the entire sole of the foot or upon the under surface of the toes but never upon the tips of the toes as do the Ungulata. The carnivorous structure is common to all of the class but the carnivorous habit, though general is not universal. Living representatives vary in size from the little active ermine to the powerful grizzly bear. The Rodents include a group of small to moderately large animals the most prominent and universal character of which is their dentition. Canine teeth are absent. The deeply set incisors, separated by a considerable vacant interval from the molars, are long and flat edged and are of paramount importance. Since they lengthen by persistent growth they serve admirably for vigorous chisel-like cutting of hard materials, hence the name "gnawers". The animals are usually plantigrade, often burrowing not infrequently arboreal, and occasionally aquatic. They are today represented by the squirrels, prairie-dogs, rabbits, rats, mice, beavers, porcupines, and a host of others. The Ungulates (Herbivores) are plant-feeding animals with hoofs rather than claws or nails, and with limbs perfected for running and not for climbing and grasping. Viewed from the point of usefulness to man they are the most important of all animals in that they furnish him with food, clothing and working assistance.

CARNIVORA.

The Carnivora may be conveniently divided into three subdivisions (sub-orders) namely, tthe Creodonta, the Fissipedia, and Pinnipedia. Of these the Creodonts, primitive carnivores, are found only in the fossil state; the Fissipedes include our common carnivorous animals, true carnivores, and are both fossil and living. The Pinnipedes include the aberrant water-loving animals, the seals and walruses. The Creodonts are represented in our badland formation by but one family, the Hyaenodonts. The Fissipedes have many important representatives. The Pinnipedes are not represented hence need no further comments in this paper.

CREODONTA.

The Creodonts were particularly abundant and well differentiated in the earliest American Tertiary. They were evidently the predatory flesh eaters of that time, occupying much the position relative to other animals that the true carnivores have held since the extinction of these their more primitive ancestors. Of all their numerous families only two or three so far as known survived the Eocene and continued into the Oligocene. One of these, the Hyaenodontidae, the latest and most specialized, is found in South Dakota and neighboring states. The individual fossils are not abundant here although several species are represented. Professor W. B. Scott of Princeton University who has written a very full account of the Osteology of Hyaenodon tabulates the following:*

Hyaenodon crucians Leidy
Hyaenodon cruentus Leidy
Hyaenodon horridus Leidy
Hyaenodon leptocephalus Scott
Hyaenodon mustelinus Scott
Hyaenodon paucidens Osborn and Wortman.

These are all from the Middle Oligocene. Some poorly preserved remains have been found in the Lower Oligocene, but little is known of these except that, like the Middle Oligocene species, they belong to the genus Hyaenodon. The size of the individuals varies considerably but the specific differences are not great. According to Scott there is much constancy in the more important structures.

The skull of the largest, *Hyaenodon horridus,* according to Leidy, reached the size of that of the largest black bear, *Ursus americanus,* but, as pointed out by Scott, the head of the animal appears large out of all proportion to body and limbs. It is quite different in shape from that of any of the true carnivores, due in large measure to the length of the cranial region with its very lofty sagittal crest and to the extreme straightness and slenderness of the zygomatic arches, the position of which is very low down on the sides of the skull. In general the brain case is small. Other characteristic features are the great length of the lower jaw, its slenderness and the regular curvature of

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*Scott, W. B. The Osteology of Hyaenodon. Jour. Acad. Nat. Sci., Phila., Vol. 9, 1894, pp. 499-535.

its inferior border. The teeth, generally forty-two in number, are prominent and the neck is short and light compared with the large head. The body is long and apparently powerful. The legs are rather short. The fore and hind feet are much the same in size and general character, each foot having five clawed toes, the toes being relatively shorter than in most recent carnivores. Whether or not it was digitigrade or plantigrade is uncertain. It may have been semi-plantigrade.

The life habits of these animals are not entirely clear. There seems to be some reason for the early suggestion that they were perhaps semi-aquatic, but later investigation has thrown doubt upon this. Plate 24 is a restoration in life as given in Knipe's book, Nebula to Man, and Fgure 11 shows the skeleton, *Hyaenodon cruentus*, as restored by Scott.

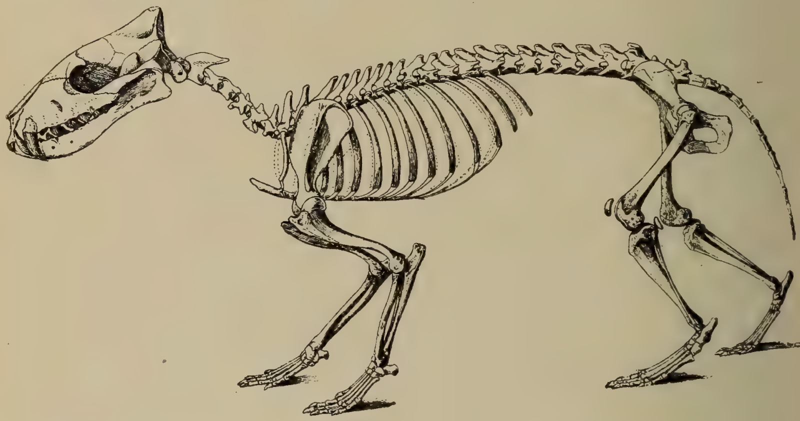

Figure 11—Restored Skeleton of *Hyaenodon cruentus*. After Scott 1895.

CANIDAE

The Canidae are abundantly represented in the badland formations of the Black Hills region. Twenty-one species are now know, of which nine are from the Oligocene and twelve from the Miocene.

The earliest North American Canidae recognized as such are found in the Upper Eocene. They first appeared in Europe at about this time also and were abundant in both Europe and North America during Oligocene and Miocene times. They are known to have reached India by the early part of the Pliocene, and seem to have migrated along the Isthmus of Panama to South America as soon as it emerged from the sea at the dawn

Hyaenodon, a Creodont Carnivore of the Oligocene. Knipe's Nebula to Man, 1905.

of Pliocene time. It is of interest to note in this connection that the nearest living allies of the Black Hills Oligocene and Miocene forms are certain foxes now inhabiting South America.

According to Cope, the Canidae, so far as concerns structure, occupy a position intermediate between the generalized carnivores, such as the raccoons, and the highest specialized forms, the cats; but in brain character they display superiority to all of the other carnivore families. The chief differences between the Tertiary and the living forms lie in the higher specialization of the latter, particularly as regards foot structure and brain character.

The Canidae seem almost certainly to have descended directly from the early Eocene Creodonta, but so undoubtedly did the Felidae. During the Oligocene time the two families were much generalized and had many characters in common, particularly in the dentition, the structure of the skull, the vertebrae, the limbs, and the feet. One feature of surprising interest, first indicated by Prof. Scott, is that some at least of the Canidae had sharp pointed, high, compressed, hooded claws, as in the cats, instead of curved, cylindrical cones, as in the dogs, and had the unmistakable ability of retracting the claws to a greater or less extent.

Although many specimens of the Canidae have been found in the badland formations of the Black Hills region, few complete skeletons have been obtained. Until recent years little had been collected but heads. Partly on account of the rarity of complete skeletons and partly on account of inherent difficulties in the nature of the species the phylogenetic history of the various families has not been very satisfactorily worked out. The following species are represented:

Lower Oligocene.

Daphoenus dodgei, Scott

Middle Oligocene.

Daphoenus vetus, Leidy.
Daphoenus hartshornianus (Cope).
Daphoenus felinus, Scott.
Daphoenus nebrascensis (Hatcher.)
Daphoenus inflatus (Hatcher.)
Cynodictis gregarius (Cope.)
Cynodictis lippincottianus (Cope.)

Upper Oligocene.

Cynodictis temnodon, Wortman and Matthew.

Lower Miocene.

Nothocyon gregorii, Matthew.
Nothocyon vulpinus, Matthew.
Nothocyon annectens, Peterson.
Nothocyon lemur, Cope.
"Amphicyon" superbus, Peterson.
Enhydrocyon robustus, Matthew.
Enhydrocyon crassidens, Matthew.
Cynodesmus thomsoni, Matthew.
Cynodesmus minor, Matthew.

Upper Miocene.

Aelurodon saevus (Leidy.)
Aelurodon haydeni (Leidy.)
Ischyrocyon hyaenodus, Matthew.

Of the several species named in the above list, *Cynodictis gregarius,* Figure 12, and *Daphoenus felinus,* Plate 25, are the

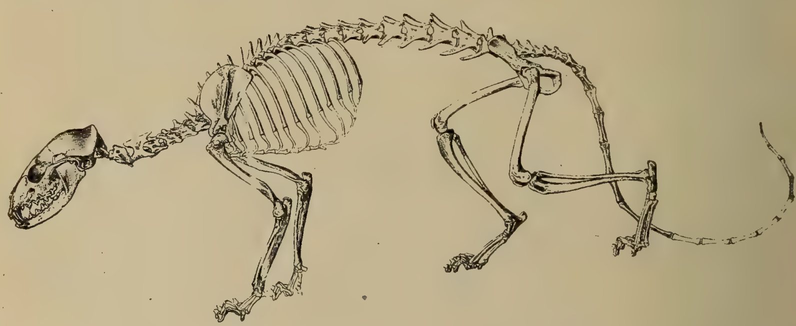

Figure 12 -Restored Skeleton of *Cynodictis gregarius.* After Matthew, 1910.

best known. Cynodictis gregarius was most abundant, and as the name implies, seems to have roved the country in packs. It was smaller than the common red fox of the eastern states. *Daphoenus felinus* was considerable larger, reaching approximately the size of the Coyote (*Canis latrans*). Both Cynodictis and Daphoenus in some of their structural characters much resembled the present day civets and Brazilian Bush dogs. In each the facial portion of the skull is short and the cranial portion long. The brain case is small, remarkably so in Daphoenus. The lumbar vertebrae are large. The tail is long and stout, much resembling that of the leopard or mungoos. In Cynodictis the hind legs are much longer than the fore legs. In Daphoenus they are more nearly equal.

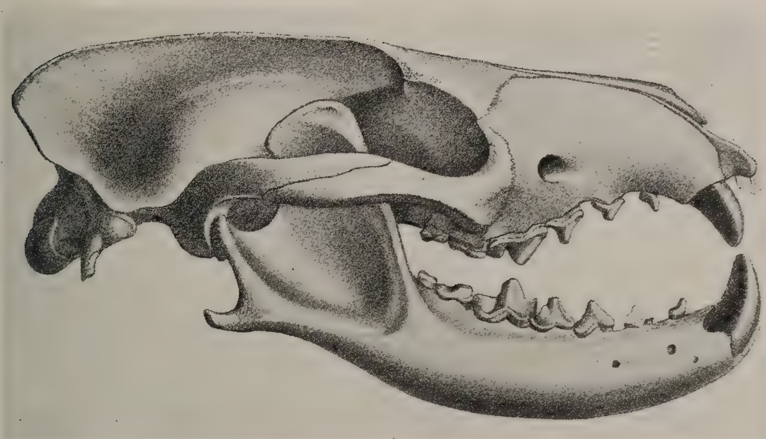

Figure 1. Head of Daphoenus felinus. Hatcher, 1902.

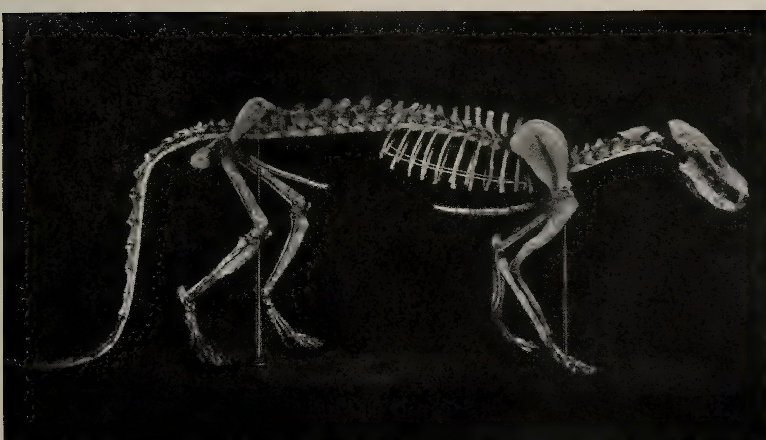

Figure 2. Skeleton of Daphoenus felinus. Hatcher, 1902.

There are five toes on each foot. Daphoenus was provided with retractile claws, much as the modern cats. In Cynodictis this was not so pronounced. The normal number of teeth in Daphoenus is forty-four, there being eleven on each side, both above and below, as follows: Incisors, three; canines, one; premolars, four; molars, three. Cynodictis lacks one upper molar on each side, leaving a total of forty-two.

Nearly all of the Miocene forms have been found within the last half dozen years. They are limited almost wholly to skulls and lower jaws. With the exception of three species described from fragmentary materials many years ago, all of the Miocene specimens have been collected and described under the direction of the American Museum and the Carnegie Museum. They were obtained chiefly from the Little White River in South Dakota, and near Agate Springs, in Sioux County, Nebraska. The largest is *Ischyrocyon hyaenodus*. The only remains obtained of this species consists of a well preserved right half of the lower jaw. It represents a young individual, the permanent teeth being only partially developed. Notwithstanding the immature nature of the jaw, its length is approximately eight and one-half inches and the full grown animal would doubtless compare favorably in size with the modern grizzly bear.*

FELIDAE

The cat family is well represented in fossil form in the Black Hills region, although neither the species nor the individuals were so numerous as were the Canidae. Two genera are of particular prominence, namely, Hoplophoneus and Dinictis. These are early forms of what are commonly known as saber-tooth cats or tigers (Machaerodonts), a name given them by reason of two great sword or saber-like canine teeth of the upper jaw. They were not so large as certain later forms of this great group, nevertheless they were vicious creatures and Hoplophoneus, Plate 27, the larger of the two, was doubtless fully as large as the present day leopard and apparently much more powerful. The two represent well separated stages in the evolution of saber-

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*Matthew, W. D., and Gidley, J. W. New or Little Known Mammals from the Miocene of South Dakota. Bull. Am. Mus. Nat. Hist., Vol. 20, 1904, pp. 241-268.

tooth cats, and while Dinictis, Figure 13, seems to have reached

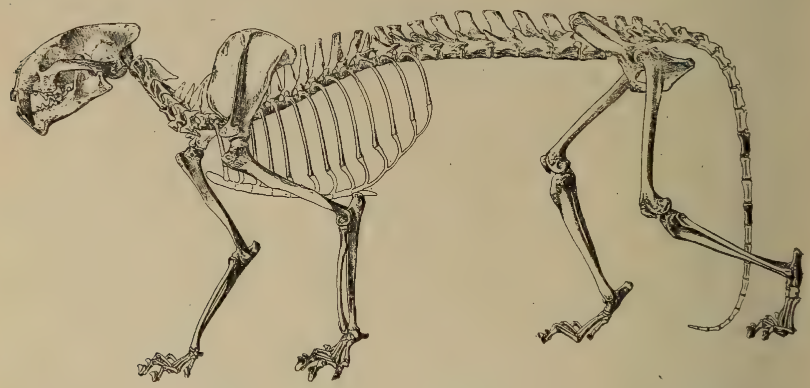

Figure 13—Restored Skeleton of *Dinictis squalidens*. After Matthew, 1901.

as high a stage of specialization as Hoplophoneus, it was evidently fitted to a somewhat different life.

The dentition varies in the different species, the number of teeth ranging from twenty-eight to thirty-four. All have three incisors and one canine on each side, both above and below. The pre-molars vary from two to three, but the molars are fairly constantly one. Only *Dinictis felina* has two on each side below.

An important feature of the lower jaw is the extreme downward projection of its anterior portion. This seems to be a coincident feature necessitated by the unprecedented development of the powerful canine teeth already mentioned. These upper canine teeth curve forward and downward nearly parallel with each other, and passing behind the much smaller lower canines, continue approximately to the lowest portion of the anterior downward prolongation of the chin. In general they are laterally compressed and the edges are more or less serrulated. They are implanted by a strong fang and reach two and one-half or three inches in length.

The cause of the development of the abnormally powerful upper canines and the uses to which they were put have been the cause of much speculation. Matthew in discussing this shows that there is definite evidence of the adaptation of the canines to a particular method of attack. The head is so shaped that good attachment is allowed for strong muscles, enabling the animal to strike downward with its saber teeth with enor-

Figure 1. Head of Hoplophoneus primaevus. Leidy, 1869.

Figure 2. Head of Syndoceras cooki. Barbour, 1905.

Hoplophoneus primaevus, a jaguar-like Saber-tooth of the Oligocene. After Osborn.
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mous power and the changes in the cranial portion allowing for the attachment for the increasingly powerful muscles were in strict correlation with the development of the saber-teeth. Along with these changes was the degeneration and change in shape of the lower jaw, allowing the mouth to be opened to an unusual extent so as to give greatest freedom to the saber-teeth in stabbing the prey. The food of Hoplophoneus must have been in large measure the thick skinned rhinoceroses, elotheres, oreodonts, and other similar animals of the time. The lighter proportioned Dinictis, with its less powerful canines, doubtless preyed more successfully on the smaller swift-footed animals, the securing of which demanded superior speed and endurance.*

The Big Badlands furnished the earliest discovered remains of Saber-tooth cats in America. Leidy, who described the first species, gave it the name *Machaerodus primaevus.* Later this was changed to *Depranodon primaevus,* and still later to *Hoplophoneus phimaevus,* the name it now bears (see Plate 26). From time to time other species have been discovered, until now eleven are known. The reader will find a helpful review of the species of cats from the badland formations of the Black Hills region, as known some years ago, in a paper by Mr. George I. Adams on the Extinct Felidae of North America, published in the American Journal of Science, volume 1, 1896, pages 419-444. The full list from the region as now recognized, is as follows:

Lower Oligocene.

Dinictis fortis, Adams.

Middle Oligocene.

Dinictis felina, Leidy.
Dinictis squalidens (Cope.)
Dinictis paucidens, Riggs.
Hoplophoneus primaevus (Leidy.)
Hoplophoneus occidentalis (Leidy.)
Hoplophoneus oreodontis Cope.

Upper Oligocene.

Dinictis bombifrons, Adams.
Hoplophoneus insolens, Adams. . .
Eusmilus dakotensis, Hatcher.

*For a fuller discussion of this, the reader is referred to the section on The Use of the Machaerodont Canine in W. D. Matthew's paper, Fossil Mammals of the Tertiary of Northeastern Colorado, Mem. Am. Mus. Nat. Hist., Vol. 1, 1903, pt. 7, pp. 385-387.

Lower Miocene.

Nimravus sectator, Matthew.

MUSTELIDAE.

The Mustelidae of the present day include the badgers, martens, weasels, ermines, skunks, otters, ratels, etc. Fossil members of the family have been found in some abundance. The more ancestral forms continue back to Eocene time, but no clearly defined species have as yet been identified in the badland formations of the Black Hills region in rocks older than the Miocene. Their description is confined to the recent writing of Mr. W. D. Matthew and of Mr. O. A. Peterson.*

Matthew first described, 1904, a fragmentary lower jaw, *Potamotherium lacota,* and a perfect lower jaw,*Lutrina pristina,* from the Upper Miocene of Little White river. Peterson, 1906, described part of a lower jaw, *Brachypsalis simplicidens,* also a poorly preserved skull, lower jaw, and other bones of *Aelurocyon brevifacies,* from the Harrison beds of Sioux County, northwestern Nebraska. Later, 1907, Matthew described a lower jaw and a portion of the skull of *Oligobunis lepidus,* also the skull, jaw and considerable parts of the skeleton of *Megalictis ferox* from the Lower Miocene of Little White river.

None of the remains discovered are complete, and nearly all are more or less mutilated. Those of *Megalictis ferox,* however, are sufficiently characteristic to indicate much of the nature of the animal. They represent a very large musteline. The head is short, wide, and massive, brain small, tail long and powerful, limbs short and stout, feet plantigrade, number of toes five, claws large and non-retractile. The animal is characterized as a gigantic wolverine, equalling a jaguar or a black bear in size, but in proportion more like the ratel. It was evidently predaceous like the wolverine, but seems to have been to some degree of burrowing disposition.

INSECTIVORA

Remains of insectivorous animals are recognized as far

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*Matthew, W. D., and Gidley, J. W. New or Little Known Mammals from the Miocene of South Dakota. Bull. Am. Mus. Nat. Hist., Vol. 20, 1904, pp. 241-271.

Peterson, O. A. The Miocene Beds of Western Nebraska and Eastern Wyoming and Their Vertebrate Fauna. Annals Carnegie Mus., Vol. 4, 1906, pp. 21-72.

Matthew, W. D. A Lower Miocene Fauna from South Dakota. Bull. Am. Mus. Nat. Hist., Vol. 23, 1907, pp. 169-219.

back as earliest Tertiary time, but the fossils are not abundant. The badland formations of the Black Hills region have yielded several forms, but they are fragmentary. They belong to the following families: first, the Erinaceidae, or hedgehogs; second, the Leptictidae, related to hedgehogs; third, the Soricidae, or shrews; fourth, the Chrysochloridae, or golden moles. The single Chysochloridae specimen was obtained from the Lower Miocene south of White river. All of the others are from the Middle Oligocene in or near the Big Badlands.

The earliest discovery of badland insectivores was made by Dr. Hayden in 1866, near one of the tributaries of White river on the occasion of his last visit to the region. The forms were described by Leidy, and consisted of one nearly complete skull designated as *Leptictis haydeni* and a fragmentary skull designated as *Ictops dakotensis.* The skulls indicate animals smaller than a mink. In life they were evidently much like present day hedgehogs, except that they were more primitive. A few years ago the American Museum of Natural History obtained remains of an animal closely related to and slightly larger than *Ictops dakotensis.* Dr. Matthew has named this animal *Ictops bullatus.*

In 1894, Mr. M. S. Farr of the University of Chicago expedition, discovered the facial portion of a skull and lower jaw which upon examination proved to belong to an ancestral shrew. Prof. W. B. Scott, who described the remains, named the animal *Protosorex crassus,* in recognition of its very primitive character. This is the first specimen of the shrew family found in the North American Tertiary.

Remains of a fossil hedgehog were obtained by Dr. Loomis of the Amherst Museum expedition in 1902. This was a fragmentary skull. It represents the first of the true hedgehogs found in America. Dr. Matthew described the form and gave it the name *Proterix loomisi.*

In 1906, Dr. Matthew identified and described meagre, but characteristic, remains of a golden mole,*Arctoryctes terrenus,* among material collected from the Lower Miocene during the summer of that year by Mr. Albert Thomson of the American Museum expedition. According to Matthew, true moles (Talpidae) are now found in the subarctic or temperate zones of all the northern continents, but not in or south of the tropics. However, in the south temperate zone, there are animals which have adopted mole-like habits and superficially resemble the true moles to a greater or less degree. The Chrysochloridae or

golden moles of South Africa are of this nature. A similar animal in fossil form has been found in the Upper Miocene of southern South America. The peculiar geographical distribution of certain animals and plants of southern lands has long been a source of speculation and study and this finding of a fossil golden mole in South Dakota so far removed from its present day and fossil relatives, adds a new feature of interest.

RODENTIA.

The rodents or gnawers constitute the largest order of mammals. Their most prominent and universal character, the dentition, shows the absence of canine teeth and the paramount importance of front teeth or incisors. They appear to have originated in North America in early Eocene time and to have been rather rapidly distributed to the other great land masses of the earth. In the Black Hills region they appear first in the Middle Oligocene, ancestral squirrels, rabbits, beavers, and rats, being represented. The beavers or beaver-like animals continue into the Upper Oligocene, the Lower Miocene and the Upper Miocene. They are particularly abundant in the Lower Miocene. Rabbits occur also in the Lower Miocene as well as certain poorly preserved forms supposed to be related to pocket gophers.

The number of specimens found indicates a considerable abundance of rodents in the region during Tertiary time, and the number of species adds emphasis to this. It happens, however, that but few complete skeletons have been obtained, the best material consisting largely of skulls and lower jaws, and in several of the species named, the description has been based on still more fragmentary material. The only complete restoration of which I know is *Steneofiber fossor* by Mr. O. A. Peterson, reproduced in Figure 14.

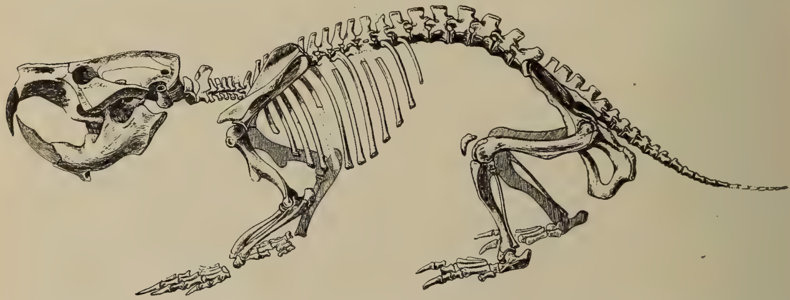

Figure 14—Restored Skeleton of *Steneofiber fossor*. After Peterson, 1905.

The earliest specimens of the rodents obtained were found by Hayden in the Big Badlands, and described by Leidy. With the exception of two other species described many years ago by Cope, little further information became available until the last few years, during which time Mr. Peterson of the Carnegie Museum, and Mr. Matthew of the American Museum of Natural History, each described a number of species.* The Carnegie Museum material has come chiefly from northwestern Nebraska and eastern Wyoming, the American Museum material from Little White river.

The commonest fossil is Steneofiber. This is especially abundant in the Lower Rosebud beds of Little White river and in the Harrison (Daemonelix) beds in northwestern Nebraska and in eastern Wyoming. Entoptychus, the gopher-like rodent, seems to be fairly common in the Little White river area also. Peterson found many specimens of *Steneofiber fossor* in close association with the Devil's Corkscrews of the Harrison beds and, as referred to elsewhere, suggests the reason for the association. This animal was smaller generally than the present day beaver. Its skull is comparatively large, the lower jaws heavy, neck short, limbs and feet powerful, tail round, rather heavy and of moderate length. Peterson states that the limb presents a striking similarity to that of other burrowing rodents and approaches that of the mole in its position. The elongated and narrow scapula of the mole, the heavy clavicle, the strongly built humerus, and the broad foot with the long and powerful ungals, is rather suggestive of the habits of this animal, which was probably burrowing to a considerable degree. The animal is related to the beaver, but is evidently not in the direct line of ancestry.

The following is a list of all species determined up to the present time:

Middle Oligocene.

Castoridae—Ancestral beavers.

Entypomys thomsoni, Matthew.

Ischyromidae—Ancestral squirrels and mormots.

Ischyromis typus, Leidy.

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*Peterson, O. A. Description of New Rodents and Discussion of the Origin of Daemonelix. Mem. Carnegie Mus., Vol. 2, 1905, pp. 139-202.

Matthew, W. D A Lower Miocene Fauna from South Dakota. Bull. Am. Mus. Nat. Hist., Vol. 23, 1907, pp. 169-219.

Muridae—Ancestral rats and mice.
Eumys elegans, Leidy.
Leporidae—Ancestral hares and rabbits.
Palaeolagus haydeni, Leidy.
Palaeolagus turgidus, Cope.
Upper Oligocene.
Castoridae—Ancestral beavers.
Steneofiber nebrascensis (Leidy.)
Lower Miocene.
Castoridae—Ancestral beavers.
Euhapsis brachyceps, Peterson.
Euhapsis gaulodon, Matthew.
Steneofiber pansus, Cope.
Steneofiber fossor, Peterson.
Steneofiber barbouri, Peterson.
Steneofiber simplicidens, Matthew.
Steneofiber sciuroides, Matthew.
Steneofiber brachyceps, Matthew.
Geomyidae—Related to pocket gophers.
Entoptychus formosus, Matthew.
Entoptychus curtus, Matthew.
Leporidae—Ancestral hares and rabbits.
Lepus primigenus, Matthew.
Lepus Primigenius, Matthew.
Upper Miocene.
Castoridae—Ancestral beavers.
Eucastor (Dipoides) tortus, Leidy.
Mylagaulus—(?)
Mylagaulus monodon, Cope.

RHINOCEROTOIDEA

The finding of fossil bones of true rhinoceroses in the Big Badlands by Alexander Culbertson in 1850, and their prompt and accurate identification by Leidy, constitute one of the most interesting, unexpected, and instructive paleontological discoveries of America.

Existing rhinoceroses are confined to Africa, the Indian Archipelago and the southern parts of Asia. These form but a small remnant of a numerous ancestry that abounded in North America from middle Eocene to late Miocene time and in Europe from Eocene to Pliocene time.

INSERT ON PAGE 88.

UNGULATA.

The order Ungulata (Herbivores) as now constituted includes the mammals once loosely classed as Ruminants, and Pachyderms. The earliest known forms much resemble the primitive Carnivores. The ancestors of both seem to have been omnivorous.

For some reason there appeared very early among the Ungulates a tendency to develop the herbivorous type of tooth and the digitigrade foot (walking upon the tips of the toes). The change in the foot from the five toed plantigrade form progressed along two different lines and thus there were produced two very different types, namely, the odd-toed type and the even-toed type. In the odd-toed type the axis of the foot is in the third or middle digit (mesaxonic). Animals of this type are known as Perissodactyls. Their present day representatives are the horse, the tapir, and the rhinoceros. In the even-toed types the axis of the foot is between the third and fourth digits (paraxonic). Animals of this type are known as Artiodactyls. Their present day representatives are the hog, hippopotamus, chevrotain, camel, lama, deer, giraffe, antelope, ox, sheep, goat, bison, et cetera. The Ungulates occurring in the badland formations of the Black Hills region are grouped as follows:

PERISSODACTYLS. Rhinocerotoidea, Lophiodontidae, Tapiridae, Equidae, Titanotheriidae.

ARTIODACTYLS, (page 103). Elotheriidae, Dicotylidae, Leptochoeridae, Anthracotheriidae, Oreodontidae, Hypertragulidae, Camelidae, Cervidae.

All rhinoceroses, living and extinct, are divided by Osborn into three subdivisions, as follows:* The Hyracodontidae or cursorial (upland) rhinoceroses; the Amynodontidae or aquatic rhinoceroses, and the Rhinocerotidae or true (lowland) rhinoceroses. Of these the first two are found only in the fossil state, the third is found both fossil and living. In America, the cursorial rhinoceroses are found first in the Middle Eocene, the aquatic rhinoceroses in the Upper Eocene, and the true rhinoceroses in the Lower Oligocene. The first two became extinct here in the Oligocene, but the true rhinoceroses endured until after the close of the Miocene. All three occur in fossil form within the area described in this paper, the cursorial and aquatic species in the Oligocene, chiefly in the Middle Oligocene, the true rhinoceroses throughout both the Oligocene and the Miocene.

The three families differed greatly from one another, both in exterior form and in dental and skeletal structure. The Hyracodonts were small, light chested, swift footed, hoofed, hornless creatures, much resembling the Miocene horses and evidenty well-fitted for living on the grass-covered higher lands. The Amynodonts were heavily built, short-bodied, hornless animals, with spreading padded feet, four functional toes in front, eyes and nostrils much elevated supposedly for convenience in swimming, canine teeth enlarged into recurved tusks, and a prehensile upper lip, apparently tending toward proboscoid development. The animal evidently much resembled the present day hippopotamus, both in build and in habit (see Plate 29). One adult skeleton, that of *Metamynodon planifrons* in the American Museum of Natural History, measures nine and one-half feet long and four and one-half feet high at the shoulders. The true rhinoceroses began as light limbed, hornless animals, intermediate in proportion between the two just mentioned, and in size and structure not greatly unlike the modern tapirs. During much of their early life history they, like the more primitive Hyracodonts and Amynodonts, were entirely without horns.

The true rhinoceroses constitute in many respects the most important of the three subdivisions and to the paleontologist are of profound interest. They lived in great abundance in the region of the Black Hills during Oligocene and Miocene time, and their skeletons in certain favored localities, particularly in the Big Badlands and in Sioux County, northwestern Nebraska, have been collected in large numbers. The Oligocene forms

*Osborn, H. F. The Extinct Rhinoceroses. Mem. Am. Mus. Nat. Hist., Vol. 1, 1898, pp. 75-164, pls. XIIa-XX.

are especially characterized as being without horns, hence the old name Acerethere. The Miocene forms have generally, but not always, a rudimentary or fairly well developed pair of horns placed transversely across the anterior part of the head, hence the name Dicerathere. Present day rhinoceroses, it should be remembered, have either no horn or one or two horns, but the arrangement when horns are present is always medial, never transverse. It is of interest to note also that while all living rhinoceroses have feet that are functionally tridactyl, some of the ancestral true rhinoceroses, at least so far as concerns the front feet, were functionally tetradactyl. This is known to be true of *Trigonias osborni,* and is suspected of others. This lessening of the number of functional toes corresponds to similar alterations in other animals and indicates progressive change. Indeed, the rhinoceroses show in many ways gradual transformations, particularly with reference to the feet, the teeth, and the development of horn cores. Osborn states that *Caenopus copei,* by a beautfiul series of transitions, passes into *Caenopus occidentalis,* and this in turn, by steady evolution through stages which might well be considered of specific value into *Caenopus tridactylus.* Likewise *Trigonias osborni,* the most primitive and least specialized true rhinoceros known, appears to stand directly ancestral to *Leptaceratherium trigonodum.* Again the Aceratheres in their later history developed nasal rugosities, and there is reason to believe that from their stock the Diceratheres developed.

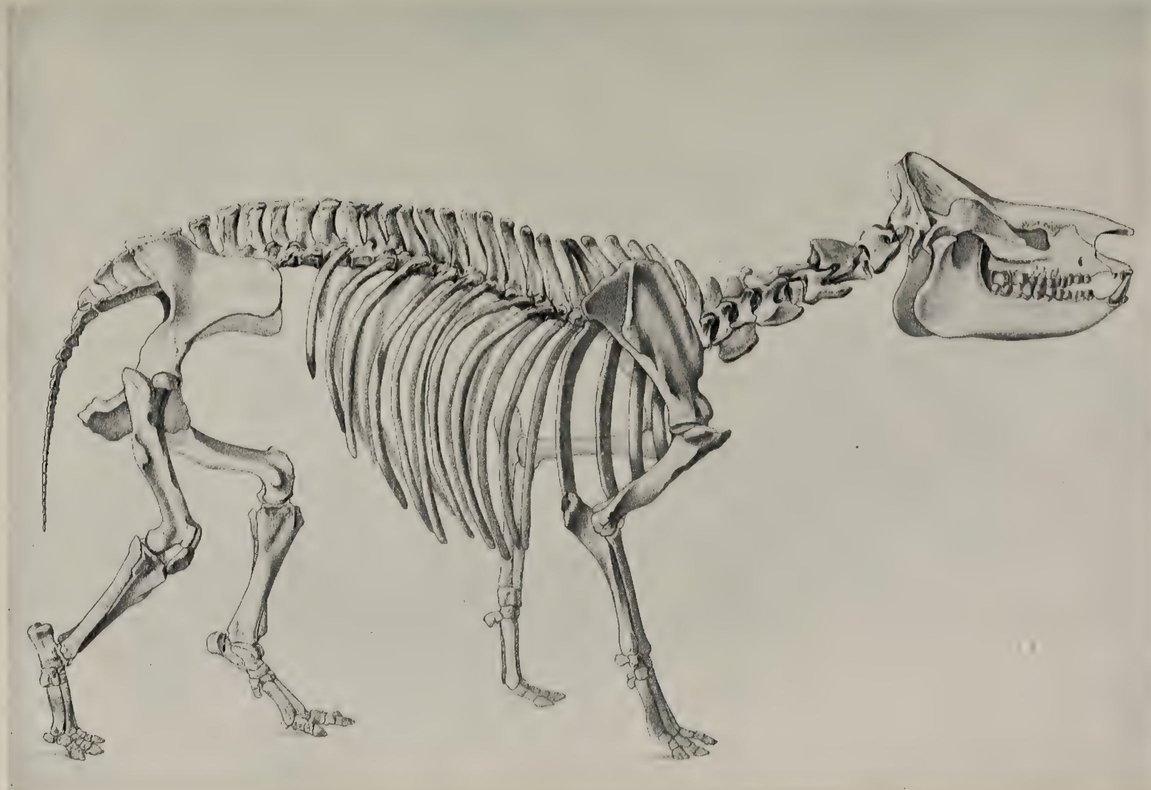
Among the Aceratheres *Caenopus mitis* was the smallest, its height at the shoulders being approximately twenty-eight inches. Among the Diceratheres *Diceratherium schiffi* was the smallest. It was also most specialized. The largest of the Aceratheres, in fact the largest of all the true rhinoceroses, seems to have been *Caenopus platycephalus.* It considerably surpassed the present day Sumatran rhinoceros. Among the others *Caenopus copei* was about the size of the American tapir and *Caenopus tridactylus,* reproduced on Plate 28, was nearly as large as the Sumatran rhinoceros. The latter specimen measures seven feet, nine inches in length, and four feet high to top of the rump.

The following list gives the species of the true rhinoceroses as well as the Hyracodonts and Amynodonts found in the badland formations of the Black Hills region:

Lower Oligocene.

Hyracodontidae.

Poor material, not named specifically.



Caenopus tridactylus, an Oligocene rhinoceros. Osborn, 1898.

Metamynodon planifrons, an aquatic rhinoceros of the Oligocene. After Osborn. Copyrighted by the Am. Mus. of Nat. Hist.

Metamynodon, a large aquatic rhinoceros; Hyracodon, a smaller running rhinoceros; and Dinictis, one of the saber-tooth tigers. All from the Oligocene. Knipe's Nebula to Man, 1905.

Amynodontidae.

Poor material, not named specifically.

Rhinocerotidae.

Trigonias osborni Lucas.
Leptaceratherium trigonodum Osborn and Wortman.
Caenopus platycephalus Osborn and Wortman.
Caenopus mitis Cope.

Middle Oligocene.

Hyracodontidae.

Hyracodon nebrascensis Leidy.
Hyracodon major Scott and Osborn.

Amynodontidae.

Metamynodon planifrons Scott and Osborn.

Rhinocerotidae.

Caenopus occidentalis Leidy.
Caenopus copei Osborn.
Caenopus simplicidens Cope.
Leptaceratherium trigonodum Osborn and Wortman.
"Hyracodon" planiceps Scott and Osborn.

Upper Oligocene.

Hyracodontidae.

Poor material, not named specifically.

Rhinocerotidae.

Caenopus tridactylus Osborn.
Caenopus platycephalus Osborn and Wortman.

Lower Miocene.

Rhinocerotidae.

Diceratherium cooki Peterson.
Diceratherium niobrarense Peterson.
Diceratherium arikarense Barbour.
Diceratherium petersoni Loomis.
Diceratherium schiffi Loomis.
Diceratherium aberrans Loomis.
Aceratherium stigeri Loomis.
Aceratherium egrerius Cook.

Upper Miocene.

Aphelops brachyodus Osborn.

Many references to the literature may be found in the List of Fossil Mammals and in the Bibliography given near the close of this paper. Among the more comprehensive papers the one by Prof. Osborn, treating of the older forms, has been men-

tioned. Another one, dealing particularly with the later forms, is by F. B. Loomis, Rhinocerotidae of the Lower Miocene. Am. Jour. Sci., vol. 26, 1908, pp. 51-64.

LOPHIODONTIDAE

The lophiodonts, closely related to the ancestral tapirs, are the most generalized of all the known perissodactyls. Prof. Hayden, in 1886, found a small fragment of a jaw in the Big Badlands, which Dr. Leidy in describing, referred to the Lophiodontidae, under the name *Lophiodon* (now *Colodon*) *occidentalis*. Later discoveries substantiated the correctness of this the first determination of a lophiodon representative found in America and added three additional species, namely, *Colodon procuspidatus, Colodon dakotensis,* and *Colodon longipes*. The first species was found in the Lower Oligocene. The last three, identified by Osborn and Wortman, are from the Middle Oligocene.*

Fossils of Lophiodonts are found elsewhere in American Tertiary, also in European Tertiary, but much of this material, like that from the Big Badlands, is fragmentary. Nevertheless, their greatly generalized nature as displayed in the material studied, indicates a group of animals of great interest. Much uncertainty prevails as to the exact relationships of the Lophiodonts, but they are known to have many of the primitive characters of the tapir, the hyracodont, and the horse.

TAPIRS.

The present day tapirs, like the horse, are the descendants of a very ancient family. Unlike the horse, however, specialization in the tapir has not advanced to a high degree, and so far as foot structure is concerned, and to a considerable extent tooth structure also, the modern representatives of the tapir are in much the same condition as the early ancestral horses. They are very similar to the Lophiodonts just described. Indeed, these animals and the ancestral tapirs show so many characteristics of such decided similarity or of such a vague nature as to render their separation and classification a matter of difficulty and some uncertainty.

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*Wortman, J. L., and Earl, Charles. Ancestors of the Tapir from the Lower Miocene of Dakota. Bull. Am. Mus. Nat. Hist., Vol. 5, 1893, pp. 159-180.

Osborn, H. F., and Wortman, J. L. Perissodactyls of the Lower Miocene White River Beds. Bull. Am. Mus. Nat. Hist., Vol. 7, 1895, pp. 343-375.

Fossil remains of the Tapiridae are comparatively rare. They, however, have had a wide geographical distribution and are known to be present in rocks of nearly every period since earliest Tertiary time. Three species have been described from the Big Badlands, one of them *Protapirus simplex,* Wortman and Earle, from the Middle Oligocene, and two, *Protapirus obliquidens,* Wortman and Earle, and *Protapirus validus,* Hatcher, from the Upper Oligocene.* These are believed to be, as the generic name implies, in the direct line of ancestry of the modern tapirs. All of the specimens secured have come from within or near the Big Badlands. The material is not abundant and consists chiefly of skulls, lower jaws, and certain limb bones.

EQUIDAE

Of all the fossils of the badland formations of the Black Hills region, perhaps none have elicited more genuine interest than those of the Equidae, or horse family. To say that these fossils represent animals of diminutive size compared with even the smallest present day horses, and that they had normally three toes on each foot, is to command at once the attention of every individual who heeds at all the phenomena of animal nature.

The ancestry of the horse is in full harmony with the proud position he holds among present day animals. No other mammal displays such a lengthy, well connected lineage, nor discloses a more beautiful handiwork in the well-ordered development of structure and habits. For perhaps three million years or more, members of the family have roamed the hills and dales of the earth, molding their nature to an ever changing environment, discarding many things inherited from their evident Cretaceous five-toed progenitors, and taking on new features leading to the exquisite relation of organs and actions in the finely-built horse of today.

The earliest known member of the family is the little Hyracotherium, or Eohippus of the Eeocene, less than one foot in height, with four well developed toes on each front foot, and three on each hind foot. Splint bones indicate the earlier pres-

*Wortman, J. L., and Earle, Charles. Ancestors of the Tapir from the Lower Miocene of Dakota. Bull. Am. Mus. Nat. Hist. ,Vol. 1, 1896, pp. 161-180.

Hatcher, J. B. Recent and Fossil Tapirs. Am. Jour. Sci., Vol. 5, 1893, pp. 159-180.

ence of five toes on the front foot and four on the hind foot, and there is good reason for believing that at some still earlier stage the pentadactyl nature was complete. In connection with the progressive enlargement of the middle toe, profound alteration also took place in other parts of the anatomy, particularly the lengthening of the jaws, increasing complexity of the teeth, pronounced elongation of the lower part of the limbs, degeneration of the ulna and fibula, et cetera.

The phylogeny of the horse was first suggested by the great French paleontologist, Cuvier. The earliest attempt at its expression was made by Kowalevsky, the Russian. He was followed in successive order by Huxley of England, Marsh, Cope, Wortman and Scott of America, and Schlosser of Germany, and more recently by Osborn and others. Interpretation by the earlier men showed inconsistencies and omissions, but with increasing collections of well-preserved material it has been possible to eliminate aberrant forms and to add needful material, until now the genealogical series is fairly complete.* For a diagrammatic representation of the more important evolutionary changes see Plate 34 from Matthew. Brief reference is made below to some features of relationship among various members of the family, but the reader desiring to pursue the subject farther, is referred to the papers listed herewith and in the bibliography inserted near the end of this bulletin.

Fortunately the fossils representing the extinct horses are abundant and often well preserved. For some years the Peabody Museum of Yale University excelled all others in the extent and importance of its collections, but more recently the

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*The following recent summary articles are among the best that have been written on the subject. The non-technical ones are readily accessible to many readers and all will be found particularly helpful:

1902. Lucas, F. A. The Ancestry of the Horse. In Animals of the Past, pp. 159-176, earlier published in McClure's Magazine (1900).

1904. Osborn, H. F. The Evolution of the Horse in America. Century Magazine, Vol. 69, pp. 3-17.

1905. Matthew, W. D. The Evolution of the Horse. Am. Mus. Journal, Vol. 3, Supplement. Guide Leaflet No. 9, (second edition), pp. 1-30.

1907. Lull, R. S. The Evolution of the Horse Family, as Illustrated in the Yale Collections. Am. Journ. Sci., Vol. 23, pp. 161-182.

1907. Gidley, J. W. Revision of the Miocene and Pliocene Equidae of North America. Bull. Am. Mus. Nat. Hist., Vol. 23, pp. 865-934.

1908. Granger, Walter. A Revision of the American Eocene Horses. Bull. Am. Mus. Nat. Hist., Vol. 24, pp. 221-264.

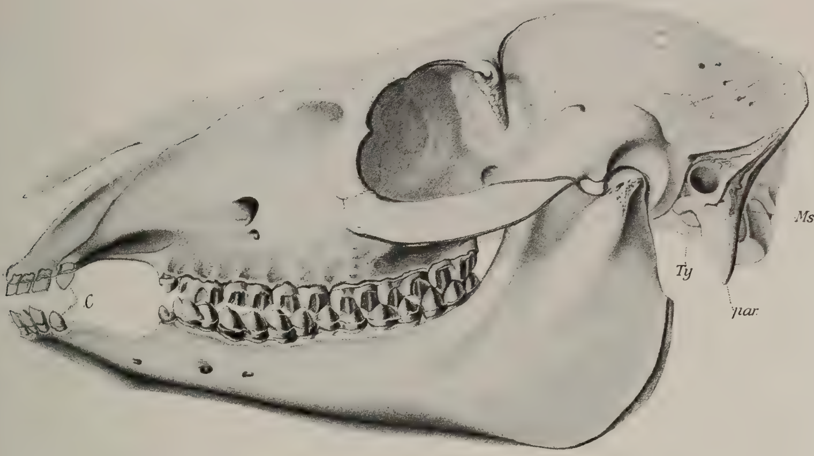

Figure 1. Head of Mesohippus bairdi, an Oligocene three-toed horse. Scott, 1891.

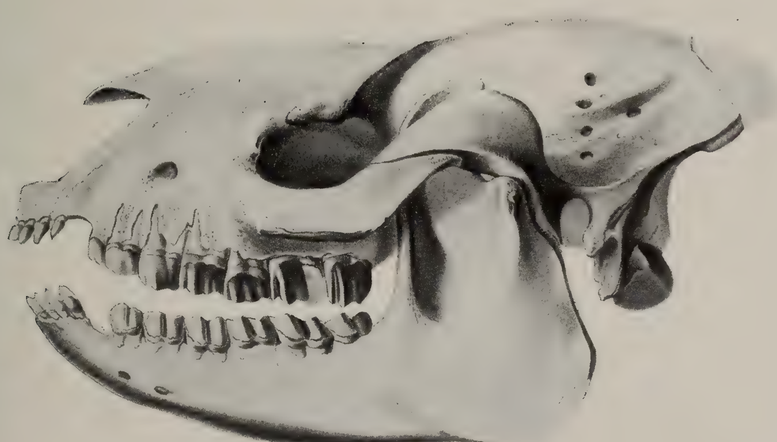

Figure 2. Head of Hyracodon nebrascensis, an Oligocene rhinoceros. Scott, 1896.

Mesohippus bairdi, the best known three-toed horse of the Oligocene. After Osborn.
Copyrighted by the Am. Mus. of Nat. Hist.

American Museum of Natural History has surpassed it. Gidley stated three years ago, 1907, that the latter collection then contained several thousand specimens—Eocene to Pleistocene, inclusive. Granger, 1908, says that the Hyracotheres (Eocene) alone were represented by several hundred specimens. Matthew and Cook, 1909, add the information that in their recent work in the Pliocene of northwestern Nebraska, they collected some hundreds of incomplete jaws and about ten thousand separate teeth, besides great numbers of limbs and foot bones. While it should be borne in mind that the above collections represent to a large extent fragmentary material, Osborn states, that in all the museums of the world there were in 1904 only eight complete mounted skeletons of fossil horses, but that of these, five were in the American Museum.

The abundance of the fossil remains and their widespread distribution geologically and geographically, clearly indicate that for ages members of the horse family ranged over the country in countless numbers. They were numerous in both North America and South America. Beginning, as they evidently did, in the earliest Tertiary or late Cretaceous in some generalized form of small height, probably no greater, according to Marsh, than a rabbit, they continued in increasing size to individuals larger than the largest draft horses of the present day. The earliest and the latest known members of the family do not occur in the deposits described in this paper, but intermediate forms are found in considerable numbers. These intermediate forms merit our chief attention.

All of the horses of the badland formations of the Black Hills region had three toes on each foot.* Those of the older formations, particularly of the Oligocene, stand approximately midway in the genealogical line and show characters of absorbing interest.

The following species have been determined:

Lower Oligocene.

Mesohippus proteulophus Osborn.
Mesohippus hypostylus Osborn.
Mesohippus celer Marsh.

*For sake of scientific accuracy it should be stated that this use of the word "horse" is an expression of relationship rather than a name of specific or generic precision. It is, however, an expressive term of much convenience and is often used in the best literature as here given.

Middle Oligocene.

Mesohippus bairdi Leidy.
Mesohippus obliquidens Osborn.

Upper Oligocene.

Mesohippus intermedius Osborn and Wortman.
Mesohippus meteulophus Osborn.
Mesohippus brachystylus Osborn.
Miohippus validus Osborn.
Miohippus gidleyi Osborn.
Miohippus crassicuspis Osborn.

Lower Miocene.

Parahippus crenidens Scott.
Parahippus nebrascensis Peterson.
Parahippus tyleri Loomis.

Upper Miocene.

Hypohippus affinis Leidy.
Protohippus perditus Leidy.
Protohippus placidus Leidy.
Protohippus supremus Leidy.
Protohippus pernix (Marsh).
Protohippus simus Gidley.
Neohipparion whitneyi Gidley.
Neohipparion occidentale (Leidy).
Neohipparion dolichops Gidley.

Of the above named species the commonest and most noted one is *Mesohippus bairdi* of the Middle Oligocene (see Plate 32). Prof. Leidy first described this in 1850 as *Palaeotherium bairdi*, but later changed the name to *Anchitherium bairdi*. Prof. Marsh in 1875 erected it into the type of a new genus, Mesohippus, hence the present name. In consequence of the fact that all of the earlier skeletons found were much broken and poorly preserved, and only the best bones saved, for forty years little was known of the animal except what could be learned from the foot bones and the head. Since 1890 several well preserved, nearly complete skeletons have been found and some of these have been described in much detail.*

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*See especially the following:

Scott, W. B. On the Osteology of Mesohippus and Leptomeryx, with Observations on the Modes and Factors of Evolution in the Mammalia. Journ. Morph., Vol. 5, 1891, pp. 301-406.

Farr, M. S. Notes on the Osteology of the White River Horses. Proc. Am. Philos. Soc., Vol 35, 1896, pp. 147-175.

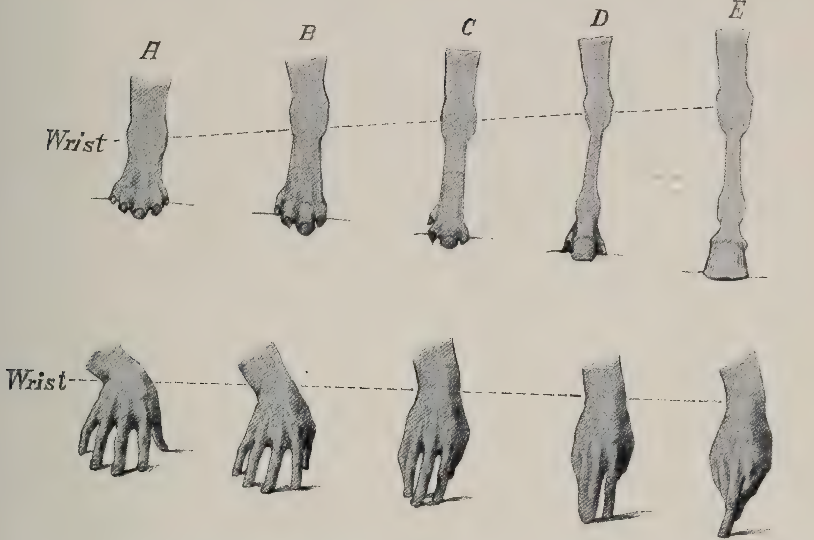

Figure 1. Illustration to show evolution of fore foot in the Horse family. After Osborn. Copyrighted by the Am. Mus. of Nat. Hist.

Figure 2. Right hind foot and left fore foot of Mesohippus intermedius, an Oligocene horse. Front and side views, Osborn and Wortman, 1895.

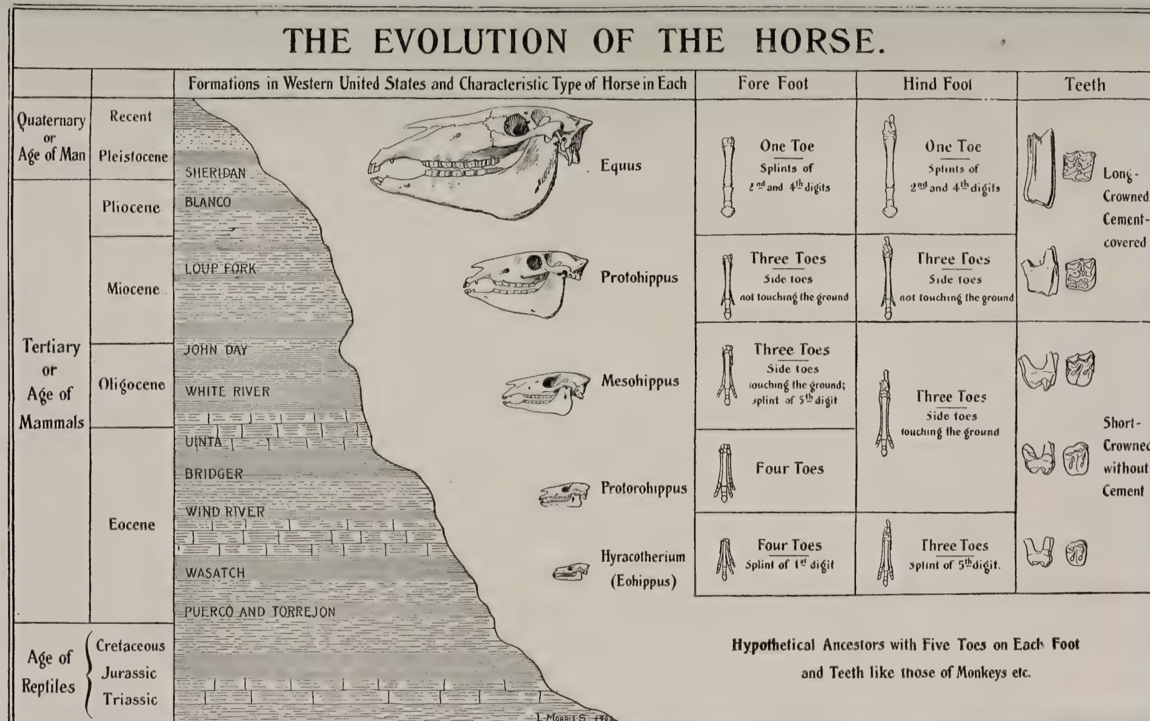

Plate showing stratigraphically the successive changes in the development of the Horse.
Matthew in Am. Mus. Jour., 1905.

The adult animal averaged about eighteen inches in height, approximately the height of the coyote. *Mesohippus celer,* a near relative, found in the Lower Oligocene, was about two-thirds this size, while *Mesohippus intermedius,* another near relative of the Upper Oligocene, averaged approximately one-third larger. *Mesohippus bairdi* was a slender-limbed creature very well adapted for speed. The hind limbs were much longer than the fore limbs, more so proportionately than in the present day horse, and the spines of the lumber vertebrae were nearly if not quite as high as those of the dorsal region, so that, according to Farr, the rump must have been much elevated above the withers if the different parts of the limbs were not very much more flexed on each other than would seem justifiable, judging from recent animals. Scott states that the obliquity of the faces of the dorsal and lumbar vertebrae show that the back was decidedly arched.

The skull was about seven inches in length (see Plate 31). The brain was large and apparently well convoluted. It weighed about one-third as much as the brain of the average present day horse. The number of teeth was forty-four, the arrangement on each side, above and below, as follows: Incisors, three; canines, one; pre-molars, four; molars, three. They were of the crested or lophiodont type and show the intermediate stage in the conversion of the short, round-knobbed enamel covered crown, into the long, sharp-crested crown of cement, dentine and enamel, as in the present day horse, so arranged that the unequal density of these tissues produces a hard, uneven grinding surface at all stages of wear.

The most striking feature is the tridactyl nature of the feet. There were three well-developed toes on each foot, fore and hind. These represent the second, third and fourth toes of five-toed animals. In addition to these, a splint bone on each fore foot represents the fifth toe, and a small nodule of bone is recognized as being the last lingering remnant of the first toe. The middle or third toe is longer and larger than the lateral ones and terminates in an enlarged, somewhat triangular bone, corresponding to the hoof bone of the present horse. Plate 33 shows in a striking way the general nature of the changes in the obliteration of the lateral toes and the enlargement of the middle one, the intermediate stage of which Mesohippus represents. "As the hand is raised, we can understand why the thumb disappears first, (Eohippus stage), because it was the first to leave

the ground; why the little finger disappeared second (Protorohippus stage), as the next shortest of the series; why the toes corresponding to the index—and ring—fingers (Mesohippus stage) for an enormously long period helped to support the middle finger. Pursuing the comparison further, we can understand how the wrist is transformed into what is falsely called the knee of the horse, the back of the hand into the cannon-bone of the horse, the fingers into the pastern, the finger-nails into the hoofs."*

Among the later horses from the badland formations, *Neohipparion whitneyi* of the Upper Miocene is noteworthy. The type specimen found on Little White river by Mr. H. F. Wells of the American Museum expedition of 1902, and described by Mr. Gidley in 1903, is the most perfect fossil horse skeleton ever discovered.† Osborn states that the preservation of the skeleton is extraordinary, even the rib cartilages being found in place as well as the tip of the tail.‡ The skeleton, approximately forty inches high, was that of a mare, and was found in association with the incomplete skeletons of five colts. It was proportioned like the Virginia deer, "delicate and extremely fleet-footed, surpassing the most highly bred modern race-horse in its speed mechanism, and with a frame fashioned to outstrip any type of modern hunting horse, if not thoroughbred."

Notwithstanding the highly developed nature of its skeleton Neohipparion represents a side branch of the horse family and for some reason, like Hypohippus, the "forest horse" and Parahippus, became extinct. Protohippus, an animal of about the same size as Neohipparion, survived and established for itself, as did the earlier Mesohippus, a definite place in the genealogical line leading to Equus of today.

TITANOTHERIIDAE

The Titanotheres are the largest animals found in the badland formations of the Black Hills region. With the exception of turtles and Oreodons they are also the most abundant.

Dr. Hiram A. Prout of St. Louis, in 1846 and 1847, described briefly in the American Journal of Science a portion of the lower jaw of one of these animals, the first specimen ever obtain-

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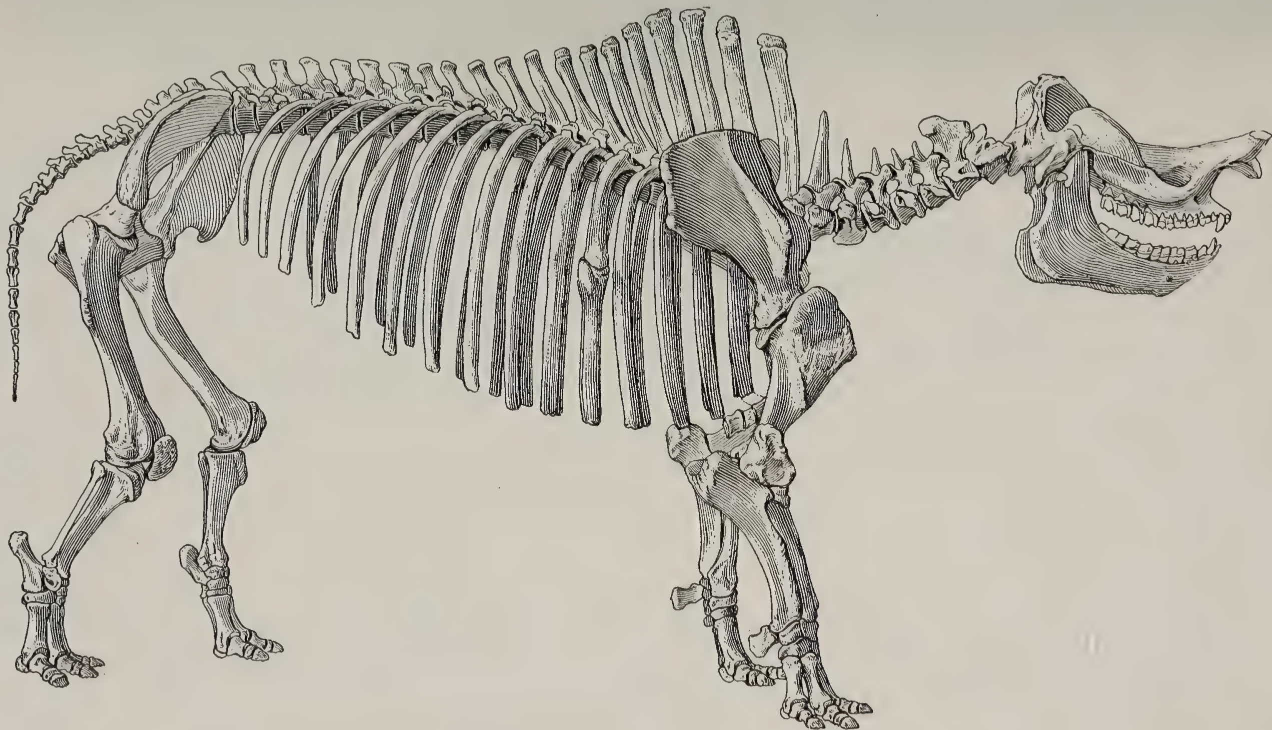
*Osborn, H. F. The Evolution of the Horse in America. Century Mag., Vol. 69, 1904, p. 7.

†Gidley, J. W. A New Three-toed Horse. Bull. Am. Mus. Nat. Hist., Vol. 19, 1903, pp. 465-476.

‡Osborn, H. F. The Evolution of the Horse in America. Century Mag., Vol. 69, 1904, pp. 3-17.



Skeleton of the large Titanothere, Megacerops robustus, from Corral Canyon, approximately one twenty-fifth natural size. **Osborn and Wortman, 1895.**

Fig. 1

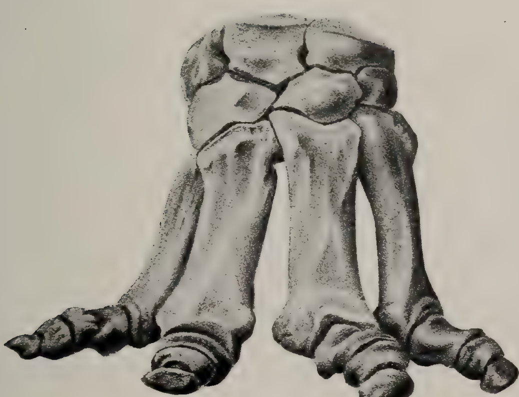


Fig. 2

Fig. 3

Figure 1. Right hind foot of Titanothere. Marsh, 1876.
Figure 2. Right fore foot of Titanothere. Marsh, 1876.
Figure 3. Right hind limb of Titanothere (Megacerops). Lull, 1905.

ed from the Big Badlands, and called it a Paleotherium (see Figure 2). Later the true character of the specimen was recognized, a new name was necessitated, and Titanotherium (Titan-beast), suggested by Dr. Leidy in 1852, came into use. Since the finding of the earliest specimen many species have been described, representing according to present usage, five genera. In consequence of the readjustment required by the rules governing paleontological nomenclature, Titanotherium, as originally used, is now recognized as co-equal with the several other genera, namely, Megacerops, Allops, Symborodon, and Brontotherium, while the term Titanothere, by reason of its significance and usefulness, is recognized as the general term under which the various subdivisions are placed. Anyone wishing to trace in detail the history of the development of Titanothere names should consult Prof. Osborn's Titanothere Contributions No. 3, and No. 4, in the Bulletin of the American Museum of Natural History, 1896 and 1902.*

The genera are distinguished from each other chiefly by differences in tooth and horn structure and by differences in the shape of the head. Osborn indicates the characters as follows: The species of Titanotherium have long skulls (dolichocephalic), persistently long and broad nasals, short triangular horns placed slightly in front of the eyes, vestigial incisors ranging from two to none above and below, and large canine teeth. Megacerops species have broad skulls (brachycephalic), nasals progressively shortening, short horns rounded or oval in section, shifting anteriorly, one or two pairs of incisor teeth above and below, and medium sized canine teeth. Symborodon species have skulls of varying proportion, horns elongate and peculiar in being placed above the eyes instead of shifting forwards, incisors vestigial, two to none above and below and canines small. Brontotherium includes the largest Titanotheres. They have very broad zygomatic arches, nasals shortening while horns elongate and shift forwards; incisors persistent, in the males two above and two below, canines short and obtuse. Allops is closely related to Megacerops, but differs from it in horn characters. The following species, all from the Lower Oligocene, have been identified from the Black Hills region:

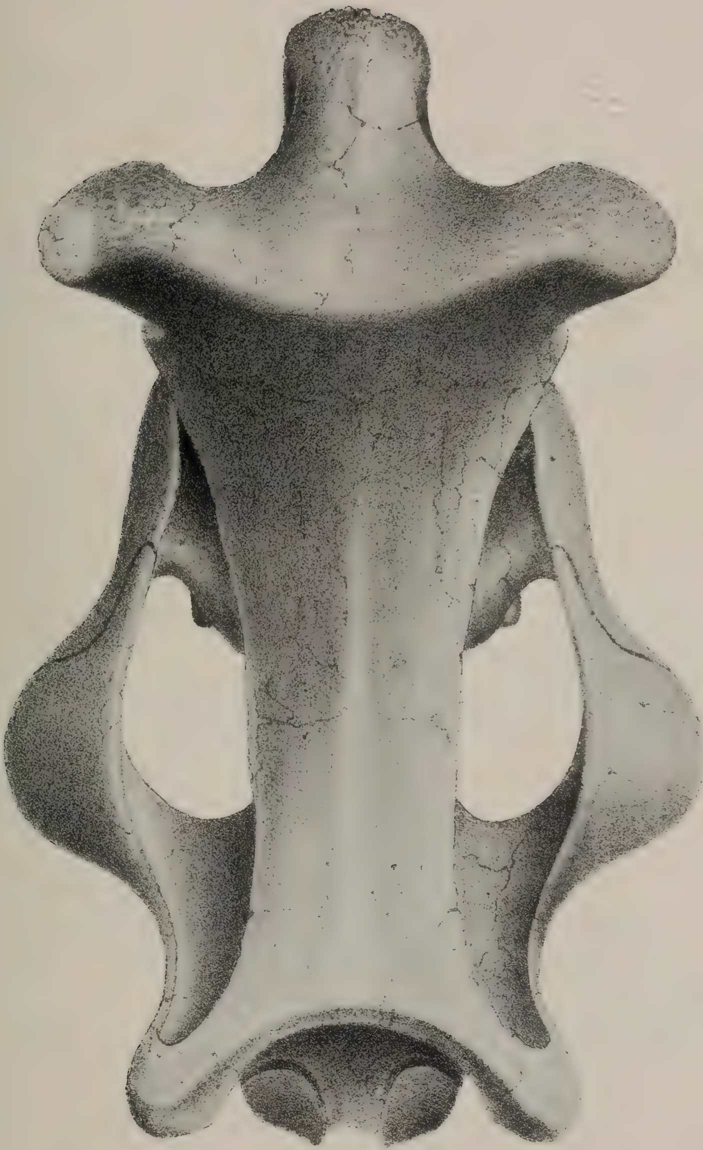
Titanotheriidae (Brontotheriidae).

Titanotherium prouti Leidy.

*It may be of interest here to state that since 1900, Prof. Osborn has had in preparation a special Monograph on the Titanotheres. This is to be published by the United States Geological Survey.

Titanotherium helocerus (Cope).
Titanotherium trigonoceras (Cope).
Titanotherium ingens (Marsh).
Megacerops dispar (Marsh).
Megacerops tichoceras (Scott and Osborn).
Megacerops robustus (Marsh).
Megacerops brachycephalus Osborn.
Megacerops bicornutus Osborn.
Megacerops marshi Osborn.
Allops seratinus Marsh.
Allops crassicornis Marsh.
Allops amplus (Marsh).
Symborodon montanus (Marsh).
Brontotherium ramosum (Osborn).
Brontotherium dolichoceras (Scott and Osborn).
Brontotherium platyceras (Scott and Osborn).
Brontotherium leidyi Osborn.
Brontotherium hatcheri Osborn.
Symborodon copei Osborn.

Mr. Hatcher in 1886, while searching for Titanothere remains in South Dakota and northwestern Nebraska, discovered that certain forms of the skulls of the Titanotheres are characteristic of certain horizons in the beds, and this indicated to him the importance of keeping an exact record of the horizon from which each skull or skeleton was taken. Continued search showed that a regular and systematic development took place in these animals from the base to the top of the beds. The most notable change was a gradual and pronounced increase in size. Hatcher says, "This increase in size from the base to the summit of the beds was attended by a very marked development in certain portions of the skeleton, noticeable among which are the following: A variation in shape and an increase in the size and length of the horncores as compared with the size of the skulls, was attended, near the summit of the beds at least, by a decided shortening of the nasals. There were also changes taking place in the dentition of these animals, especially in the number of incisors and in the structure of the last, upper, true molar. The number of incisors, though probably never constant, even in the same species, shows a tendency to decrease in skulls found near the summit of the beds. At the base of the beds the number of incisors is from one to three on a side,



Skull of Titanotherium ingens viewed from above. The anterior end is toward the top of the plate. Marsh, 1874.

Fig. 1

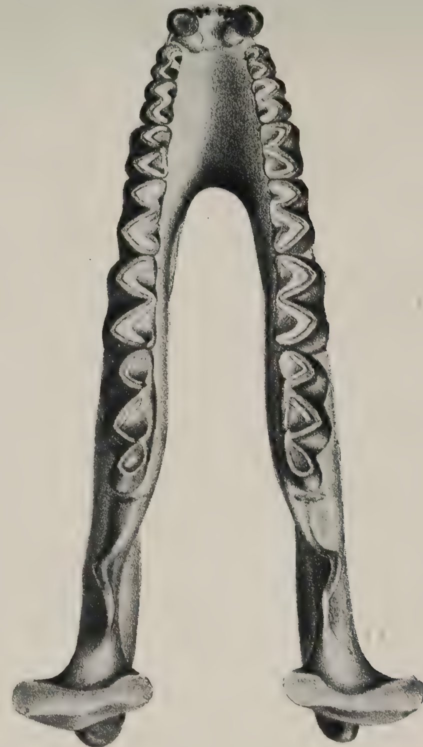


Fig 2.

Figure 1. Upper teeth of Titanothere. Marsh, 1876.
Figure 2. Lower jaw of Titanothere. Marsh, 1876.

Both figures much reduced. Figure 2 reduced more than Figure 1.

while at the top there are never more than two on a side, often only one, sometimes none. In skulls from the very lowest beds the incisors have already become so rudimentary as to be no longer functional. As would be expected, the number of incisors decreased after they became of no functional value. In the matter of incisors the Titanotheriidae at the time of their extermination, were in a fair way to accomplish just what the somewhat related, but more persistent, Rhinocerotidae have nearly succeeded in doing, viz., the elimination of the incisor dentition."*

According to Hatcher, the Titanotheres had their origin in early Eocene time, were of considerable importance throughout the Bridger and Uinta periods, reached their culmination during Lower Oligocene time, and became wholly extinct at the close of the latter period. They present one of the most interesting illustrations known of rapid evolution in size and special characters followed by quick extinction. They developed slowly at first, and although their ancestors may be traced for perhaps half a million years, they seem to have left absolutely no descendants. Outside of North America the Titanotheres have been recognized only in the Balkan Mountains.

During the time of their greatest development the Titanotheres were the largest of all the mammals in the localities where they lived. They were well prepared by size and offensive weapons for combating the attacks of predaceous animals and they were possessors of perhaps the most efficient dental equipment ever developed for masticating coarse vegetable food, such as evidently flourished in abundance in the region at that time. Their size was comparable to that of the present day elephant, averaging slightly smaller.

Of the restorations that have been made, the earliest one, the skeleton of *Titanotherium prouti* from the Upper Titanotherium beds described by Scott and Osborn in Bulletin Museum Comparative Zoology, 1887, indicates an animal more than twelve feet long and approximately eight feet high at the shoulders. The skeleton of *Megacerops robustus,* Plate 35, from the Upper Titanotherium beds, restored by Osborn and Wortman, 1895, measures thirteen feet, eight inches in length, seven feet, seven inches in height, and breadth across the pelvis three feet, ten inches. This would indicate an animal fourteen feet or

*Hatcher, J. B. The Titanotherium Beds. Am. Nat., Vol. 27, 1893, pp. 204-231.

more in length and fully eight feet high. A restoration of *Megacerops dispar* from the Lower Titanotherium beds, described by Hatcher in Annals Carnegie Museum, 1902, is somewhat smaller than either of the above, but the exact size is not given. It was the finding of nearly complete remains of a Megacerops that afforded Marsh the opportunity to make his early restoration. This is described in American Journal of Science, 1889, but as in Hatcher's description, exact measurements are not given. Doubtless skulls and other bones have been found, particularly of the Brontotherium, that would indicate larger Titanotheres than those represented in the restorations, but the measurements given will perhaps serve to represent average sizes of well developed individuals.

In addition to the restorations just indicated, the following restorations in the flesh are noteworthy: *Megacerops* (*Brontops*) *robustus* in Hutchinson's Extinct Monsters, second edition, 1893; Titanothere Family (*Brontotherium gigas*) in Osborn's Prehistoric Quadrupeds of the Rockies, Century Magazine, Vol. 52, 1896, p. 709; Megacerops in Lull's Restoration of the Titanothere Megacerops, American Naturalist, Vol. 39, 1895; Titanotherium (Brontops) in Knipe's Nebula to Man, 1905.

Plate 39 is a reproduction of the restoration of Titanotherium as given by Knipe. Plate 40 is a reproduction of Osborn's *Brontotherium gigas,* but representing a different view from that published in the Century Magazine.

In general appearance the Titanothere showed some resemblance to the rhinoceros, particularly as to the head. The limbs are stouter than in the rhinoceros, the fore limbs especially so. The limbs have some likeness to those of an elephant, but are shorter and apparently more supple. There are four short thick hoofed toes on the front foot corresponding to the second, third, fourth, and fifth of five toed animals. On the hind foot only the second, third, and fourth are present (see Plate 36). The body of the animal is short, as in the elephant, and the shoulder is conspicuously high, much as in the bison. This is caused by the great elongation of the spinous process of the anterior dorsal vertebrae. These projecting parts have well roughened extremeties and doubtless served to support in great measure the stout muscles required to manipulate the powerful head in feeding and to give opportunity for its aggressive use.

The skull, (Plate 37), is particularly grotesque and noteworthy. It is a long, low, saddle-shaped affair, with remarkable nasal prominences at the extreme end, bearing in most species,

Titanotherium (Brontops) from the Oligocene. Knipe's Nebula to Man, 1905.

Brontotherium gigas, a flat-horned titanothere, the largest Badland animal of the Black Hills region. After Osborn. Copyrighted by the Am. Mus. of Nat. Hist.

especially the later ones, powerful horns or horn-cores. The skull varies much in the different genera and species, considerably in the different sexes, and individual variation is not uncommon. Its full length in some of the larger species reaches as much as three feet or even more. The width is generally less than two feet, although in occasional skulls, especially of Brontotherium, it may reach more than thirty inches.

The horn-cores are more or less cellular at the base and are placed transversely and project upward and outward. Their size, shape and position, like other parts of the skull, vary much with species and sex. The ears are placed far to the rear, while the eyes are surprisingly near the front. The brain, like the brain of nearly all early mammalian types, was very small. The teeth, usually thirty-eight, were large. This is particularly true of the grinders in the upper jaw. Not infrequently in the larger species the well-fanged, nearly square upper molars measured more than four inches in diameter. Plate 38 is a reproduction of the teeth as given by Marsh in the American Journal of Science many years ago. The neck was short and stout and the head in ordinary position was evidently held declined. The Titanothere was a perissodactyl and a pachyderm. The nature of its thick skin is not positively known, but relying on skeletal characters common to thick-skinned animals, the restorations that have been made, such as are reproduced in Plates 39 and 40, are believed upon considerable evidence to be within reasonable limits of accuracy.

Notwithstanding the abundant Titanothere remains that have been found, complete skeletons are rare. Hatcher in 1902, gives the total number in the whole country as four, as follows: One in the Carnegie Museum, from War Bonnet creek, northwestern Nebraska; one at Yale University, from near Chadron; one in the American Museum of Natural Histry, from the Big Badlands; and one in Princeton Museum from the Big Badlands. Of these the Carnegie Museum skeleton is from the Lower Titanotherium beds, the other three from the Upper Titanotherium beds.

ELOTHERIDAE AND DICOTYLIDAE.

Few fossil animals of the region of the Black Hills have afforded more real puzzling features than the ancestral swine. Several genera and a number of species have been identified, including several classed as ancestral peccaries, but usually the material is fragmentary and confined mostly to the head and

lower jaws. Elotherium is the best known genus, its skeleton being represented by considerable material. Marsh and Scott have each published restorations of this animal, and Scott has described its various structural features in much detail.* Of the ancestral peccaries (Tagassuidae) Desmathyus (Thinohyus), is best known. Peterson has described specimens of these from northwestern Nebraska.†

Elotherium was evidently a very grotesque animal (see Plates 41 and 42). Considered as indirectly ancestral to present day swine, it nevertheless showed few of the distinct suilline characters. In not a few respects it resembled the hippopotamus. Its size varied considerably, ranging in some species to near the size of the present day rhinoceros, the head alone reaching sometimes more than three feet in length. *Dinohyus hollandi*, a nearly related genus, had a skull whose length, according to Peterson, reached more than thirty-five inches.‡ The Elothere skull is remarkable in many ways. The muzzle is long and slender, the eyes shifted far back, the cranium short, brain cavity absurdly small, the sagittal crest high and thin and the zygomatic arches enormously developed. Other odd features are the pendent compressed plates given off from the ventral surface of the jugals and two pairs of knob-like processes on the ventral borders of the lower jaw. In young individuals the knob-like processes are only rough elevations, in some adults, especially the smaller species, they are little more than rounded knobs, but in the larger forms they become greatly elongated and club-shaped. Their use seems to be wholly unknown. The dentition above and below on each side is as follows: incisors, three; canines, one; pre-molars, four; molars, three; total, forty-four. The canines, both above and below, are large and powerful. They do not appear to be of any sexual significance as the females developed them as fully as the males. Their use seems to have been that of digging up roots, in view of the fact that certain well preserved specimens show deep grooves on the posterior side of the lower teeth near

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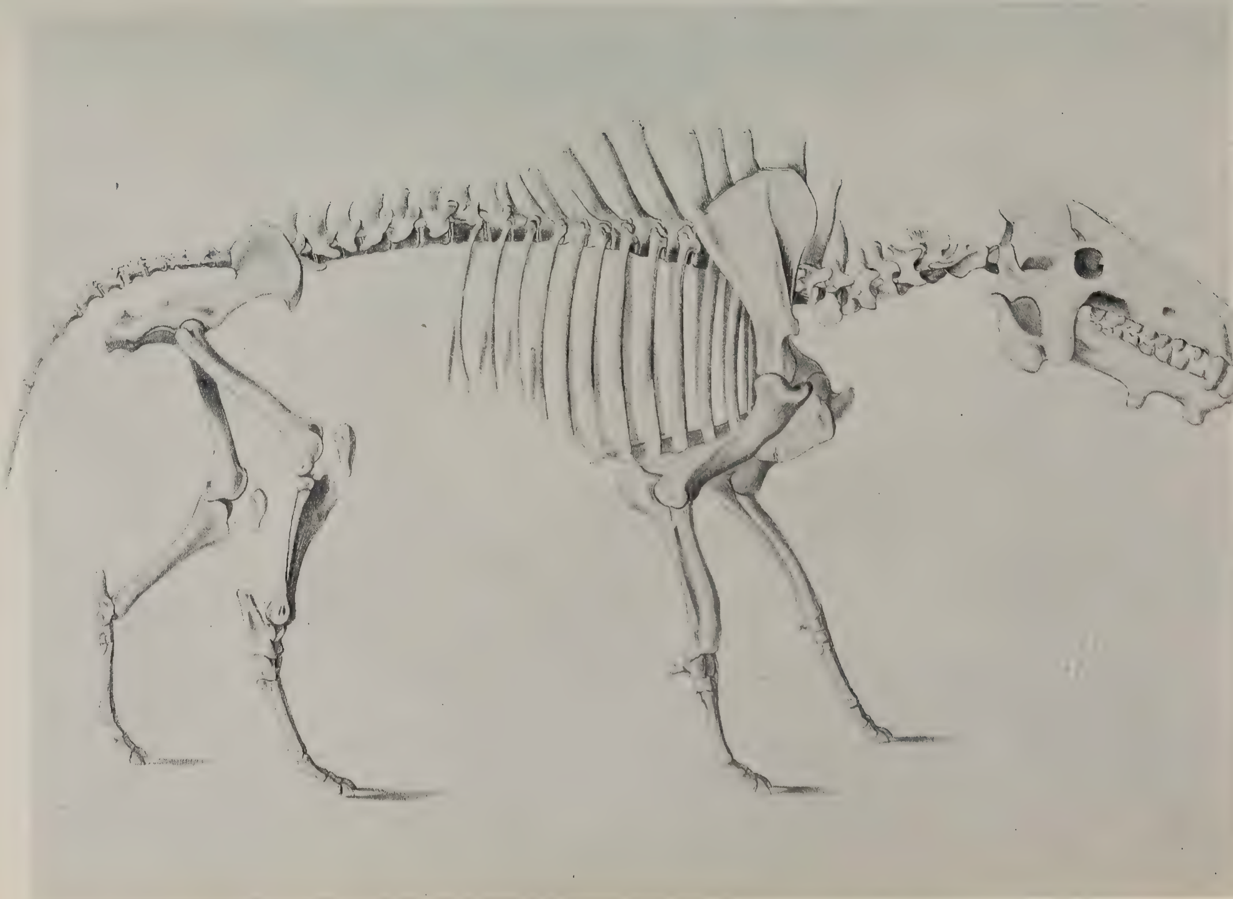
*Marsh, O. C. Restoration of Elotherium. Am. Jour. Sci., Vol. 47, 1894, pp. 407-408. 1 pl.

Scott, W. B. The Osteology of Elotherium. Trans. Am. Philos. Soc., Vol. 19, 1898, pp. 273-324. 2 pls.

†Peterson, O. A. New Suilline Remains from the Miocene of Nebraska. Mem. Carnegie Mus., Vol. 2, 1906, pp. 305-324, 2 pls.

‡For a recent careful description of *Dinohyus hollandi* including excellent restorations of the skeleton and of the animal in life, see the following: Peterson, O. A., A Revision of the Entelodontidae. Mem. Carnegie Mus. vol. 4, 1909, pp. 41-156, pls. 54-62.



Skeleton of Elotherium (Entelodon) ingens, a giant suilline Artiodactyl of the Upper Oligocene. Scott, 1898.

Elotherium (Entelodon) imperator, a giant suilline Artiodactyl of the Upper Oligocene. After Osborn.
Copyrighted by the Am. Mus. of Nat. Hist.

the gums, grooves that could not have been caused by the attrition of the other teeth. The neck is short and massive and well arranged for the attachment of strong muscles necessitated by the great length and weight of the head. The limbs are long, particularly the fore limb, and this in connection with the high shoulder prominence, gives to the animal a peculiar stilted appearance. The foot, fore and hind, has two functional toes corresponding to the third and fourth of five toed animals. The second and fifth are present, but only in rudimentary form.

Much that has been said in regard to the structural features of the Elotheres applies also in a general way to the Dicotylidae, but the latter represent a later development and tend more definitely toward the modern peccaries.

The following list includes all of the species known from the badland formations of the Black Hills region, both of the Elotheridae and the Dicotylidae:

Elotheridae (Entelodontidae).
- Lower Oligocene.
  - *Elotherium* (*Entelodon*) *crassum* Marsh.
- Middle Oligocene.
  - *Elotherium* (*Entelodon*) *mortoni* (Leidy).
- Upper Oligocene.
  - *Elotherium* (*Entelodon*) *ingens* Leidy.
  - *Elotherium* (*Entelodon*) *crassus* Marsh.
  - *Elotherium* (*Entelodon*)*bathrodon* Marsh.
- Lower Miocene.
  - *Dinohyus hollandi* Peterson.

Dicotylidae (Tagassuidae).
- Middle Oligocene.
  - *Perchoerus probus* Leidy.
  - *Perchoerus nanus* (Marsh).
- Upper Oligocene.
  - *Perchoerus robustus* (Marsh).
  - *Perchoerus platyops* (Cope).
- Lower Miocene.
  - *Desmathyus siouxensis* (Peterson).
  - *Desmathyus pinensis* Matthew.
- Upper Miocene.
  - *Prosthemnops crassigenis* Gidley.

Concerning all of the above forms, it may be said that they with the Suidae were apparently derived from a common Eocene ancestry. The Dicotyline group is first clearly distinguished from the others in the Oligocene Perchoerus. According to Matthew and Gidley the peccaries originated in the new world and have always remained here, while the true pigs (suinae) originated in the old world and never of their own accord reached the new world, their presence here now of the latter being due solely to introduction by man since the discovery of America by Columbus.

LEPTOCHOERIDAE.

Three species of Leptochoeridae are recorded from the Middle Oligocene of the Black Hills region. Two are from the Big Badlands and one from northwestern Nebraska. Leidy in 1856 described certain teeth which he designated as *Leptochoerus spectabilis* and later additional teeth and a fragmentary jaw were considered as referable to the same species. Marsh in 1894 described another species *Leptochoerus gracilis,* his material consisting of an adult skull and much of the skeleton in fine state of preservation, the animal being "about as large as a rabbit." Still later Hatcher, 1901, described *Stibarus quadricuspis* from fragmentary material. Leidy in his early work stated that the teeth indicate an animal of a somewhat suilline nature and Marsh's studies on more complete material affirm Leidy's suggestion.

ANTHRACOTHERIIDAE

The Anthracotheriidae include species of an extinct family of stoutly built, generalized, primitive animals, with teeth approaching the selenodont shape, and evidently resembling to some extent the present day pig but having some characters possessed by the hippopotamus. Their nearest important relatives of the time were apparently the Oreodontidae. These they resembled very closely. Scott states that the likeness as shown in the skull, teeth, vertebrae, limbs, and feet, is fundamental and indicates a common pentadactyl ancestry of perhaps middle Eocene time.

Fossils representing various species of the family are widely distributed over the earth, more particularly in the old world. The name Anthracotherium (Coal-beast) arises from the fact that their remains were first discovered in coal deposits,

the brown-coal deposits of Savoy. Leidy many years ago described the first American species under the name *Hyopotamus americanus*. This consisted of only a fragment of a jaw with some teeth and until recent years little information of American material has been available. Five species, all from the Oligocene, are now recognized from the badland formations of the Black Hills region. They are as follows:

Lower Oligocene.
- *Hyopotamus* (*Ancodon*) *americanus* Leidy

Middle Oligocene.
- *Anthracotherium curtum* Marsh
- *Hyopotamus* (*Ancodon*) *rostratus* Scott.

Upper Oligocene.
- *Anthracotherium karense* Osborn and Wortman.
- *Hyopotamus* (*Ancodon*) *brachyrhynchus* Osborn and Wortman.

Of the two genera the Hyopotami are generally of lighter build. For a restoration of *Hyopotamus* (*Ancodon*) *brachyrhynchus* see Figure 15. For additional details of desccription the

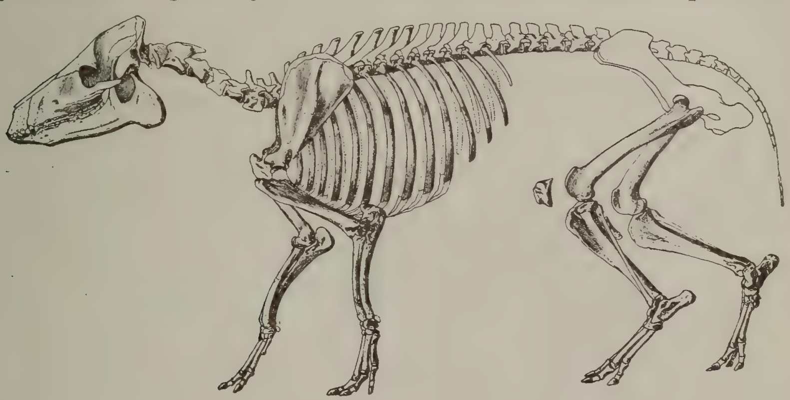


Figure 15—Restored skeleton of *Hyopotamus* (*Ancodon*) *brachyrhynchus*. After Scott, 1895.

reader will find the following papers of value: Scott, W. B. The Stucture and Relationships of Ancodus. Journ. Phila. Acad. Nat, Sci., vol. 9, 1894, pp. 461-497 and p. 536. Osborn H. F., and Wortman, J. L., Fossils of the Lower Miocene White River Beds. Collection of 1892. Bull. Am. Mus. Nat. Hist., vol. 6., 1894, pp. 199-228. Family Anthracotheriidae pp. 219-223. Matthew, W. D. Observations upon the Genus Ancodon. Bull. Am. Mus. Nat. Hist., vol. 26, 1909, pp. 1-7.

OREODONTIDAE

The Oreodontidae include the commonest fossil mammals of the badland formations of the Black Hills region. Representatives of the family are found only in North America. They originated in the Eocene, ranged through the Oligocene and Miocene and became extinct in Lower Pliocene. They are distinguished by many primitive characters and according to Cope they constitute one of the best marked types of Mammalia the world has seen. They occupy a position somewhat intermediate between the ruminants (cud-chewing animals) and the suilline pachyderms (pig-like thick-skinned animals).

The skull, Plates 43 and 44, has to some extent the form of the present day peccary. The cranial portion is much like that of the camel. The skeleton as a whole more nearly resembles that of the pig, but the number, general proportions, relative position and plan of construction of the teeth are more nearly those of the ruminants and it is this relationship to the ruminants that has governed the classification of the family. Leidy in his description of the Oreodon suggested that it might very appropriately be called a "ruminating hog." One remarkable feature is the highly developed canine teeth in both jaws. These teeth or tusks are three sided with rounded borders, the upper pair curving forward, downward and slightly outward, the lower pair nearly or quite straight and pointing upward, forward, and outward. They give to the jaws something of the appearance of the wolf's jaws but it is only a resemblance and does not indicate any close relationship. As in the pigs the eyes were small, the neck and legs short. With the exception of the older forms all of the Oreodontidae had four toes on each foot. These represent the second, third, fourth, and fifth of five toed animals. Agriochoerus and the far commoner Oreodon had five on the front feet. The tail was long and slender. The animals varied considerably in size but the common forms were about the size of the peccary.

Following is a list of the species found within the Black Hills region:

Lower Oligocene.

Oreodon (*Merycoidodon*) *hybridus* Leidy.
Oreodon (*Merycoidodon*) *affinis* Leidy
Oreodon (*Merycoidodon*) *bullatus* Leidy

Middle Oligocene.

Agriochoerus antiquus Leidy.

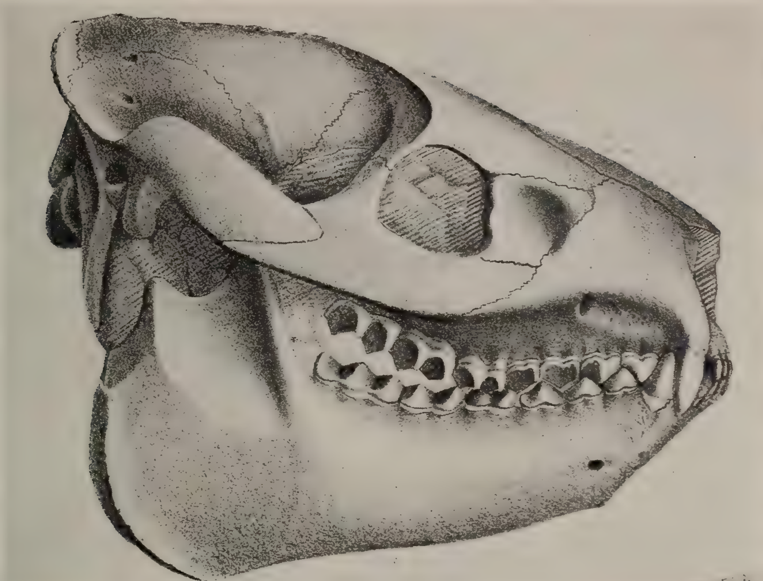


Figure 1. Head of Oreodon (Merycoidodon) gracile. Leidy, 1869.

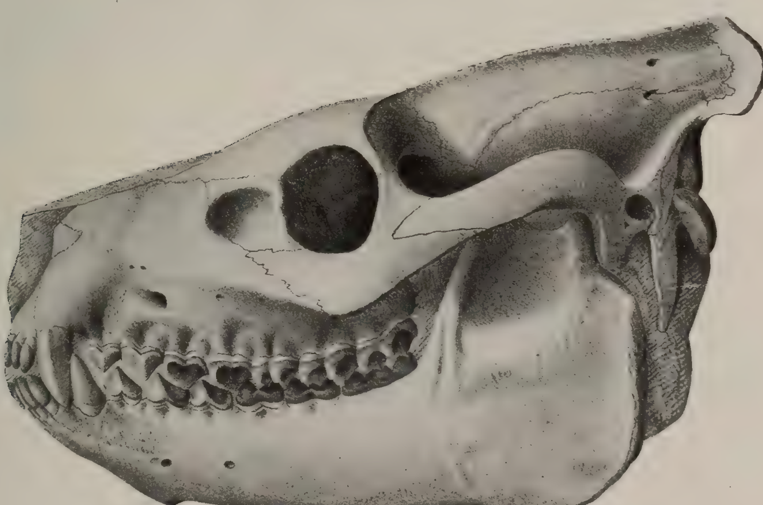


Figure 2. Head of Oreodon (Merycoidodon) culbertsoni. Leidy, 1869.

Figure 1. Skull of Eporeodon major. Leidy, 1869.

Figure 2. Left half of skull of Eporeodon major, as seen from above. Leidy, 1869.

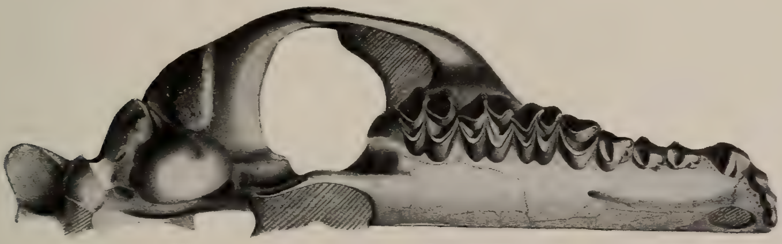


Figure 3. Right half of skull of Eporeodon major, as seen from below. Leidy, 1869.

Agriochoerus latifrons Leidy.
Oreodon (Merycoidodon) culbertsoni Leidy.
Oreodon (Merycoidodon) gracilis Leidy.
Oreodon (Merycoidodon) sy cf bullatus Leidy.

Upper Oligocene.

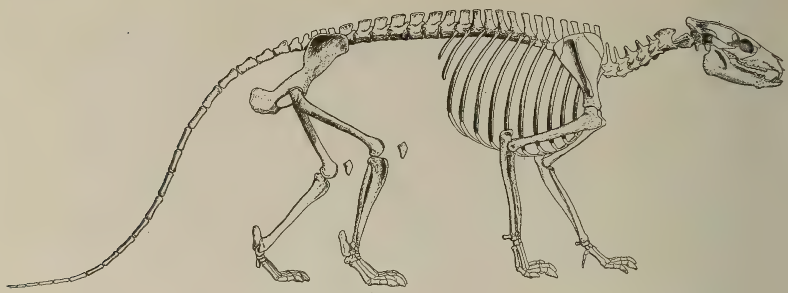
Agriochoerus major Leidy.
Agriochoerus gaudryi Osborn and Wortman.
Agriochoerus migrans Marsh.
Eporeodon (Eucrotaphus) major Leidy
Eucrotaphus jacksoni Leidy.

Lower Miocene.

Mesoreodon megalodon Peterson.
Promerychochoerus carrikeri Peterson.
Promerychochoerus vantasselensis Peterson.
Phenacocoelus typus Peterson.
Merychyus elegans Leidy.
"Merychyus" harrisonensis Peterson.
Leptauchenia decora Leidy.
Leptauchenia major Leidy.
Leptauchenia nitida Leidy.
Merychyus minimus Peterson.

Of the several genera in the above list Oreodon, Leptauchena, Agriochoerus, and Promerychochoerus are the best known. Oreodon is by far the most abundant, but the others are found in considerable numbers. They seem to have ranged in great herds over the Oligocene and Miocene lands of South Dakota, Nebraska, Colorado, Wyoming, Montana and North Dakota. It is interesting in this connection to note that the Oreodontidae, in addition to giving their name to the Oreodon beds of the Middle Oligocene furnished names also for three of the zones above the Middle Oligocene, namely, the Leptauchenia zone, the Promerychochoerus zone, and the Merycochoerus zone.

Leptauchenia was founded on fossil remains obtained by Prof. Hayden in 1855 from near Eagle Nest butte. This animal is of interest in that its structure seems to indicate an aquatic habit. The teeth resemble somewhat those of the llama (Auchenia) hence the name Leptauchenia. Agriochoerus, the restored skeleton of which is reproduced in Figure 16, is remark-

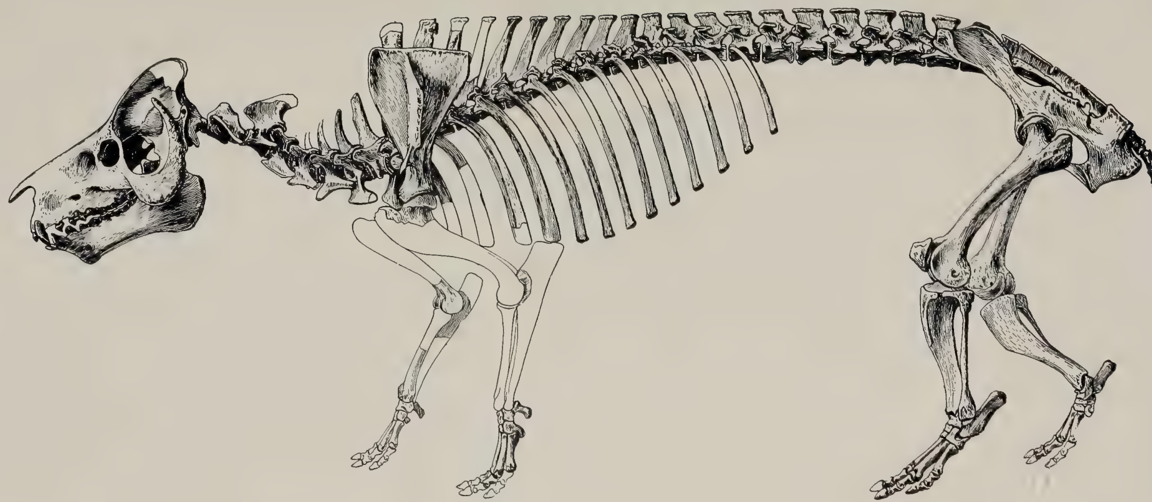


Fignre 16—Restored skeleton of *Agriochoerus latifrons*. After Wortman, 1896.

able in that its toes were apparently armed with claws instead of hoofs and the first toe (the thumb) of the fore foot seems to have been opposable. Aside from its foot structure the animal was much like the Oreodon. It was approximately three feet long not including the rather long tail. Mesoreodon is likewise remarkable in that the thyroid cartilage of the larynx was ossified much as in the howling monkey and according to Prof. Scott it must have had most unusual powers of voice.

Promerycochoerus, a larger and heavier animal than those of the earlier genera, has been found in considerable numbers in northwestern Nebraska and eastern Wyoming. Plate 48 shows the restored skeleton of *Promerycochoerus carrikeri*. This skeleton is more than five and one-half feet long and evidently indicates a large bodied slow moving animal the habits of which as has been suggested were perhaps somewhat the same as those of the hippopotamus. Peterson describes the animal briefly as having a massive head, a short, robust neck, dorsal vertebrae provided with prominent spines, lumbar vertebrae heavy, thoracic cavity capacious, and the feet large.

The Oreodons are found in the Lower and Middle Oligocene and are particularly common in what is known as the "lower nodular layer" (red layer) of the Middle Oligocene fifteen or twenty feet above the Titanotherium beds. It is on account of the abundance of these fossils and their early discovery in the Middle Oligocene that this division of the badland formations was by Hayden given the name of Oreodon beds. Leidy tells us that as early as 1869 he had observed fossils of approximately five hundred individuals among the collections sent him for study. Few general badland collections fail to show specimens of these interesting creatures, but most



Skeleton of Promerycochoerus carrikeri, an Artiodactyl of the Lower Miocene. Peterson, 1906.

of the material is made up of skulls and detached bones. Few complete skeletons have been obtained and until recent years little attempt was made at restoration. The dentition is remarkably complete the total number of permanent teeth being forty-four arranged in nearly unbroken series in both jaws. The formula for each side above and below is as follows: Incisors three; canines, one; premolars, four; molars, three. Total forty-four. Of the Oreodons *Oreodon culbertsoni* is by far the most common. Leidy says that of the five hundred he had observed about four hundred and fifty were of this species. *Oreodon gracilis,* about two-thirds as large as *Oreodon culbertsoni,* was perhaps the next in abundance. Its skull was about the size of the red fox and a skeleton mounted by Mr. C. W. Gilmore of the U. S. National Museum measured twenty seven inches in length and is twelve and one-half inches high at the shoulders. *.Eporeodon major,* earlier called *Oreodon major,* is still rarer. It is about one-fifth larger than *Oreodon culbertsoni* or nearly twice as large as *Oreodon gracilis.*

The literature on the Oreodontidae is widely scattered through the various scientific periodicals and special publications. Many of the papers listed in the Bibliography near the close of this publication, contain descriptions of species. So far as I am informed there has been no recent exhaustive resume of the subject. Prof. Cope, many years ago, 1884, published in the Proceedings of the American Philosophical Society, Vol. 21, pp. 503-572, a synopsis of the species of Oreodontidae. Later, 1890, Prof. Scott published an important contribution to the knowledge of the subject,* but I have not had recent opportunity to examine this paper. Brief summary descriptions of more recent date may be found in several of the better encyclopedias and text books of paleontology.

HYPERTRAGULIDAE

The Hypertragulidae include some of the most interesting fossil mammals ever discovered. They are ancient selenodonts (ruminants) resembling in a way the little chevrotain or "deerlet" of India and the musk deer of the Asiatic highlands but they are in reality not closely related to either. They seem to represent an independent offshoot of the primitive ruminant stock but near relatives, either ancestral or descendent are not known.

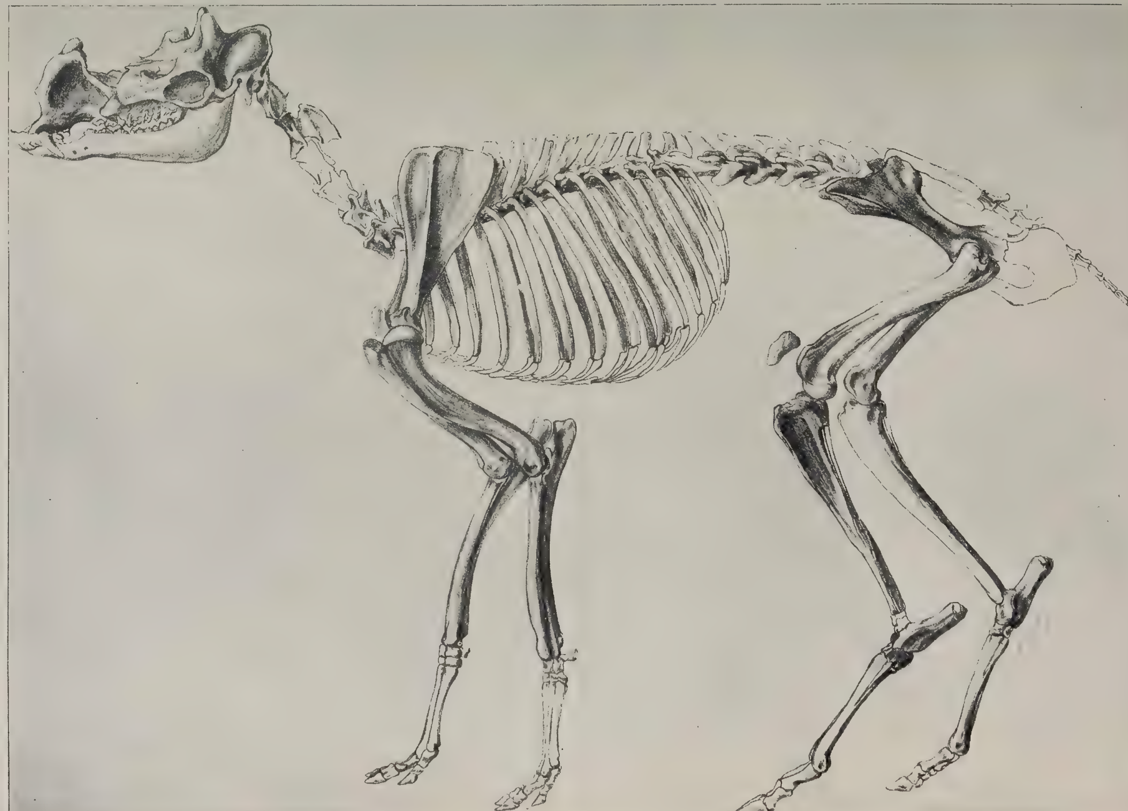
*Scott, W. B. Beitrage zur Kenntniss der Oreodontidae. Morpholog. Jahrbuch, Vol. 16, pp. 319-395, pls. XII-XVI, 10 fgs.

They are distinguished from all other American ruminants by the combination of functionally tetradactyl front feet with didactyl hind feet. Of the seven genera thus far recognized from the Black Hills region, Protoceras is the most interesting and the best known. It is found only in the Upper Oligocene and because of its importance the strata containing it are known as the Protoceras beds. Of the other genera Leptomeryx has been most carefully described but the materials available have not been so abundant nor so complete as in the case of Protoceras.

The first Protoceras specimen was obtained by Mr. J. B. Hatcher in 1890. It, like all subsequent material of this kind, was found near the highest part of the Big Badlands, where the Protoceras beds are well exposed. In January 1891 Prof. Marsh described the animal in the American Journal of Science under the name *Protoceras celer* in allusion to the early appear ance of horns in this fleet-footed group of artiodactyls. Before this discovery no horned artiodactyls were known to have lived earlier than Pliocene time. Marsh states it as an important fact that while all existing mammals with horns in pairs are artiodactyls and none of the recent perissodactyls are thus provided, the reverse of this was true among the early forms of these groups.

The head is especially unique (see Plate 46). It displays in many ways the modernized type of structure and shows sexual differences unparalelled among the ancient artiodactyls. The most obvious characters are the bony protuberances from various parts of the head in the male. In the female these are only faintly indicated. In the male a pair of protuberances project upward from the rear part of the head in much the same position as the horns of the present day pronghorn antelope. Near the anterior end of the face there is a second pair, laterally compressed and more prominent than the first pair. Over the eyes there is a third pair serving as a sort of protective awning for the eyes. In front of these and slightly nearer the median line of the face there is a fourth pair. These are much less prominent than the others mentioned but their presence is clearly indicated. Finally a fifth pair, slightly more prominent than the last, but less prominent and especially less hornlike than the others, is placed at the side of the face nearly above the anterior molar tooth.

The head is long and narrow, tapering rapidly toward the



Skeleton of Protoceras celer, a six-horned herbivore of the Upper Oligocene. Scott, 1895.

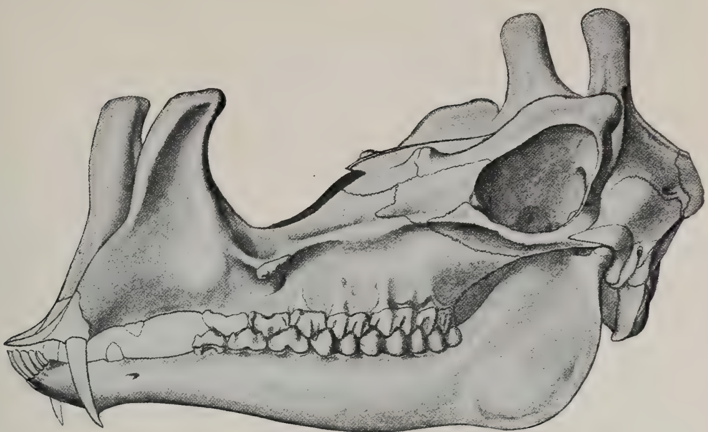


Figure 1. Head of Protoceras celer. Marsh, 1897.

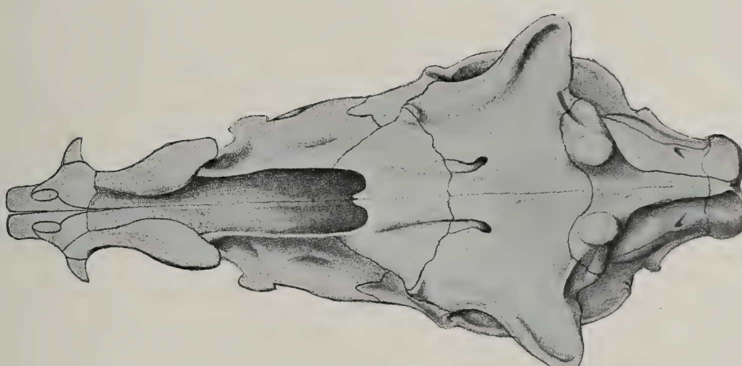


Figure 2. Skull of Protoceras celer as seen from above. Marsh, 1897.

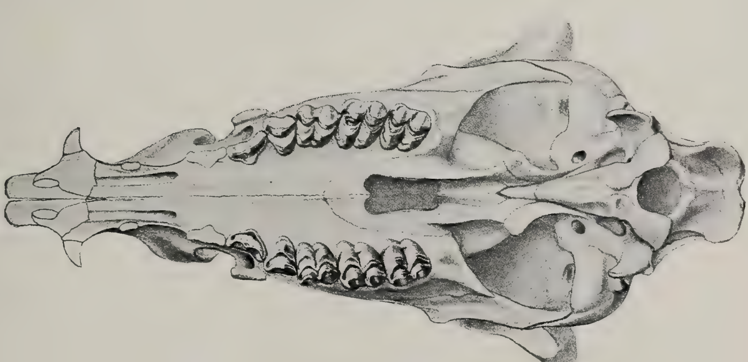


Figure 3. Skull of Protoceras celer as seen from below. Marsh, 1897.

Protoceras celer, a six-horned deer-like Artiodactyl of the Upper Oligocene. After Osborn.
Copyrighted by the Am. Mus, of Nat. Hist.

anterior end, where the muzzle becomes extremely slender. The cranium is capacious and well formed. The brain case is of good size and indicates a brain fairly well convoluted, in fact the brain development of Protoceras seems to have been more advanced than any other animals of the time. The nasals are remarkable in that they indicate a long flexible nose if not a true proboscis. Among recent ruminants such a proboscidiform muzzle is found only in the saiga antelope and to a less extent in the moose.

The dentition for each side is: Incisors none above, three below; canines, one above and one below; molars, three above and three below. The upper canines of the male are trihedral, large and prominent and project outwards and backwards.

The four toes of the front foot are functional and correspond to the second, third, fourth, and fifth, of five-toed animals. The hind foot shows only two toes, the third and fourth. Small short splint-like processes disclose, however, the rudimentary second and fifth. The hind limb compared with the fore limb, is large and long. The tail is larger and better developed than in the present day deer.

The size of Protoceras is practically that of the sheep, but the general build seems to have corresponded more nearly to that of the pronghorn antelope. It is, however, not very closely related to either. A restoration of the complete skeleton by Prof. Scott is shown on Plate 45. A reproduction of the animal in life by Mr. Charles R. Knight under direction of Prof. Osborn is given on Plate 47. The reproduction of Syndoceras, a rather distant relative of Protoceras, found near Agate Springs, northwestern Nebraska, by Mr. Harold J. Cook and described by Prof. E. H. Barbour, is given on Plate 26.

The Hypertragulidae identified to date in the badland formations of the Black Hills region are as follows:

Lower Oligocene.

Heteromeryx dispar Matthew.

Middle Oligocene.

Hypertragulus calcaratus Cope.

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*For the more extended studies of Protoceras see the following:

Osborn, H. F., and Wortman, J. L. Characters of Protoceras (Marsh), the New Artiodactyl from the Lower Miocene. Am. Mus. Nat. Hist., Bull. Vol. 4, 1892, pp. 351-371.

Scott, W. B. The Osteology and Relations of Protoceras. Journ. Morph., Vol. 11, 1895, pp. 303-374, 3 pls.

Marsh, O. C. Principal characters of the Protoceratidae. Am. Journ. Sci., Vol. 4, 1897, pp. 165-176, 6 pls.

Leptomeryx evansi Leidy.
Hypisodus minimus Cope.

Upper Oligocene.

Protoceras celer Marsh.
Protoceras comptus Marsh.
Protoceras nasutus Marsh.
Calops cristatus Marsh.
Calops consors Marsh.

Lower Miocene.

Syndoceras cooki Barbour.
Hypertragulus "calcaratus" Cope.

CAMELIDAE

The camel originated in North America. The earliest and most primitive ancestors are found here and the evidence shows that the family had traveled far on its road toward modern camels before conditions became favorable for their migration to other continents.

At present the family consists of but two genera, Camelus and Llama. Of the camels proper there are but two species, *Camelus dromedarius* or Arabian (one-humped) camel, and *Camelus bactrianus* or *Bactrian* (two-humped) camel. They inhabit the desert regions of Northern Africa, Arabia, and Central Asia. The llamas, including alpacas, guanacos, and vicunas, live only in the arid highlands of South America.

The camels are among the earliest domesticated animals of which we have knowledge and since the dawn of human history they seem not to have been known in the truly wild state. We lose ourselves in meditation as we think of the position the stupid, ungainly camel has made for himself in the history of old world transportation but let us not fail to reflect that much of the ancestral history of this creature lies at our own doorway. Ages before Joseph was sold by his brethren to the Ishmaelitic caravan from Gilead the forerunners of these useful beasts of burden were roaming in great numbers the wilds of what we now know as South Dakota and neighboring states seeking the comforts of a primitive living and looking forward in some mysterious way to the convenience of elastic pads for their feet, fleshy humps for their backs and water pockets for their stomachs.

Within the area described in this paper a dozen ancestral species have been identified, five from the Oligocene and seven

Skeleton of Oxydactylus longipes, an ancestral camel of the Lower Miocene. Peterson, 1904.

from the Miocene. These are preceded elsewhere by still older forms, the oldest of all so far as yet known being *Protylopus petersoni* a little four toed creature scarcely larger than a jack-rabbit, found a few years ago in the Upper Eocene beds of the Washakie basin, Wyoming, and described by Mr. W. B. Matthew of the American Museum of Natural History. The following are the species found in the region of the Black Hills.*

Middle Oligocene.
- *Poebrotherium wilsoni* Leidy.
- *Poebrotherium labiatum* Cope.
- *Poebrotherium eximium* Hay.
- *Paratylopus primaevus* Matthew.

Upper Oligocene.
- *Pseudolabis dakotensis* Matthew.

Lower Miocene.
- *Stenomylus gracilis* Peterson.
- *Protomeryx halli* Leidy.
- *Protomeryx cedrensis* Matthew.
- *Oxydactylus longipes* Peterson.
- *Oxydactylus brachyceps* Peterson.

Upper Miocene.
- *Procamelus occidentalis* Leidy.
- *Procamelus robustus* Leidy.

The commonest South Dakota species, the one first discovered, and the one that has received the most merited recognition is *Poebrotherium wilsoni*. The head of the animal is shown in Figure 17. The collection of Big Badland material given by Mr. Alexander Culbertson in 1847 to the Academy of Natural Sciences of Philadelphia contained a broken skull of this animal and Dr. Leidy in describing the specimen, the first of the many South Dakota badland fossil vertebrates studied by him, gave it the name it bears (see Figure 3). He first regarded the animal as allied to the musk deer but later indicated its cameloid nature. Since the description of this earliest Poebrotherium skull abundant other remains have been found but generally they have not been complete. In 1890 the Princeton expedition was fortunate in securing a very excellent

*Later forms (Pleistocene) have been found in abundance in the Black Hills region, particularly south of the South Dakota-Nebraska line, but these do not come within the scope of this paper.

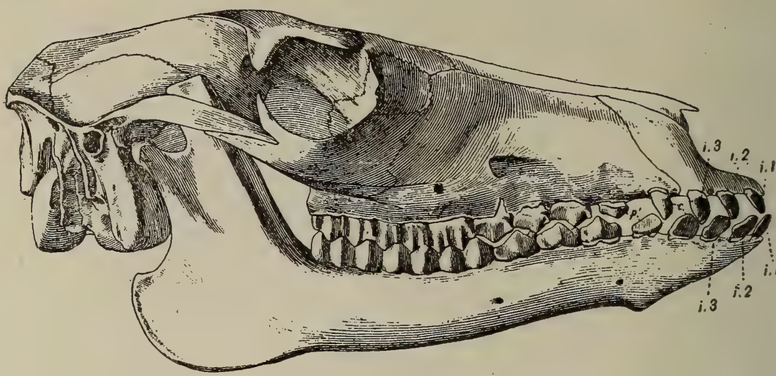


Figure 17—Head of *Poebrotherium wilsoni.* After Wortman, 1898.*

skeleton of *Poebrotherium wilsoni* almost entire and Prof. Scott has described this in a most careful manner.† It is not possible, nor would it be profitable to go into the details of this description here. Briefly it may be said that the animal was a lightly built, graceful creature with apparently some external likeness to the llama but of about the size and build of the existing gazelle. It shows its relationship in many features of its skeleton but as in many extinct animals the bones show a primitive or generalized nature, and its connection with the llamas is perhaps as close as with the true camels. The eyes are farther back than in the present day camel, the ribs more slender, and the foot, armed with small pointed hoofs was apparently without a pad. Like the existing camel the foot has only two toes, the third and fourth, but traces of the second and fifth remain as evidenced by the metapodial nodules. The metatarsal bones are separate but pressed closely together and plainly anticipate the definite union into a "cannon bone" during the subsequent Miocene. The animals varied considerably in size the larger individuals reaching a height of twenty four inches. The slightly larger, nearly related species *Poebrotherium labiatum* occasionally reached as much as twenty-eight inches. Of the other Oligocene species *Pseudolabis dakotensis* is of interest in that it is the first and only one found in the Protoceras beds. According to Matthew it apparently represents a side line of cameline descent of which nothing further is known.

*O. P. Hay in U. S. Geol. Surv. Bull, 179, p. 675 lists this as pertaining to a new species, *Poebrotherium eximinm.*

†Scott, W. B. On the Osteology of Poebrotherium. Journ. of Morph., Vol. 5, 1891, pp. 1-78.

Among the Miocene forms Procamelus has long been known. This genus is of interest in that the camels and llamas of today seem to have descended directly from it. Within the Black Hills region its remains have not been found in quantity and the much later studied genera Stenomylus and Oxydactylus have received fuller description.* Specimens of these latter have been found especially in northwestern Nebraska. A reproduction of the skeleton of *Oxydactylus longipes* as restored by Peterson is given on Plate 49. Loomis describes *Stenomylus hitchcocki* in Vol. 29, 1910, of the American Journal of Science more than forty skeletons of which were found in one excavation five miles southeast of Agate Springs. In general it may be said that the Miocene forms became increasingly more cameloid in that they are larger, the side toes disappear, the metatarsal bones become more fully united and rugosities of the hoof bones indicate the presence of a small foot pad.

With the close of the Miocene important geographical changes came about including the raising of the isthmus of Panama above sea level and the forming of a land connection across Behring Strait. In this way widespread migration became possible. The camels during and immediately subsequent to the developement of these land bridges were especially abundant and diversified throughout North America, hence readily took advantage of the opportunity to enter South America in the one direction and Asia and thence to Europe and Africa in the other. Later during Pliestocene time by reason of unfavorable climate or other conditions the North American branches of the family all died out while some at least of the more favorably situated foreign members lived on. Thus in the light of their ancestral history the wide separation of such nearly related animals as the camel and the llama, so long a perplexing question, is readily understood†

CERVIDAE

Until 1904 nothing was known of the ancestral deer within

*Peterson, O. A. Osteology of Oxydactylus. Ann. Carnegie Mus., Vol. 2, 1904, pp. 434-476. 12 pls.

Loomis, F. B. Osteology and Affinities of the Genus Stenomylus. Am. Journ. Sci. Vol. 29, 1910, pp. 297-323.

†In addition to the papers already mentioned the following general review of extinct camels published some years ago will be found of much value: Wortman, J. L. The Extinct Camelidae of North America and Some Associated Forms. Bull. Am. Mus. Nat. Hist. Vol. 10, 1898, pp. 93-142.

the region of the Black Hills. In that year Mr. Matthew described a fragmentary jaw, *Blastomeryx wellsi,* from the Upper Miocene. Three years later he refers briefly to *Blastomeryx advena* found in the Lower Miocene. In the following year, 1908, in a paper "Osteology of Blastomeryx and Phylogeny of the American Cervidae." Bull. Am. Mus. Nat. Hist., vol. 24, pp. 535-562, Mr. Matthew describes much better material than hitherto accesible, defines two new species, *Blastomeryx primus* and *Blastomeryx olcotti,* and summarizes to date the available information concerning the ancestral deer of the North American continent. Of the species found within the Black Hills region *Blastomeryx olcotti* specimens were obtained near Lusk, Wyoming. All of the others are from the Pine Ridge Indian Reservation near Little White river.

The earliest material obtained gave little information as to the definite relation of Blastomeryx to present ruminants but in the study of the later collections Mr. Matthew discovered it to be a primitive deer approximately ancestral to the American Cervidae and derivable in its turn from the Oligocene genus Leptomeryx whose relation to the Cervidae had not before been suspected. Its nearest relative structurally among the present day Cervidae is the musk deer. The general proportion of the skull is much as in the musk deer and like that animal it has no trace of horns and the upper canines are developed into long,

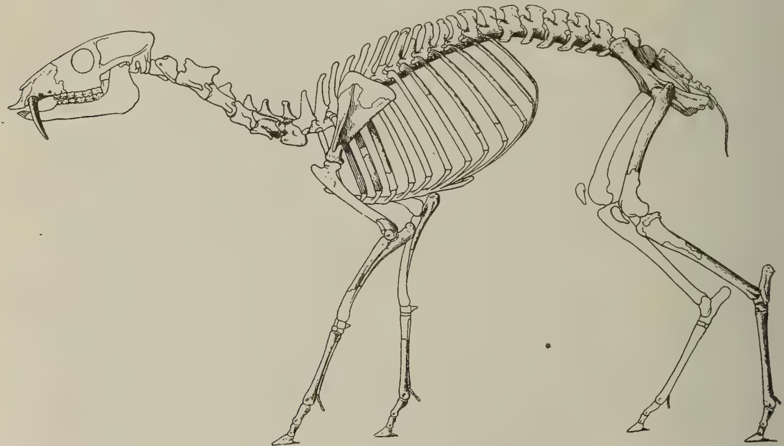


Figure 18—Restored skeleton of *Blastomeryx advena.* After Wortman 1908

slender, recurved tusks. The dentition on each side is as follows: Incisors none above, three below; canines one above

and one below; premolars three above and three to four below; molars three above and three below. The skeleton as a whole has many primitive characters but the various species all show the general cervid affinities. The animal in life stood from one to one and a half feet high at the shoulders. A reproduction of the skeleton of *Blastomeryx advena* as restored by Matthew is given in Figure 18.

TURTLES

Few Badland fossils are more abundant or more widely distributed or better preserved than the turtles. The size of the individuals varies from a few inches in length to more than two feet. Specimens three feet long are occasionally observed.* From the various Badland formations in the region covered by this paper ten species of turtles have been described. They are as follows:

Lower Oligocene.
- *Graptemys inornata* Loomis.
- *Testudo brontops* Marsh.
- *Xenochelys formosa* Hay.

Middle and Upper Oligocene.
- *Stylemys nebrascensis* Leidy.
- *Testudo thomsoni* Hay.
- *Testudo laticunea Cope.*

Lower Miocene.
- *Testudo arenivaga* Hay.
- *Testudo emiliae* Hay.

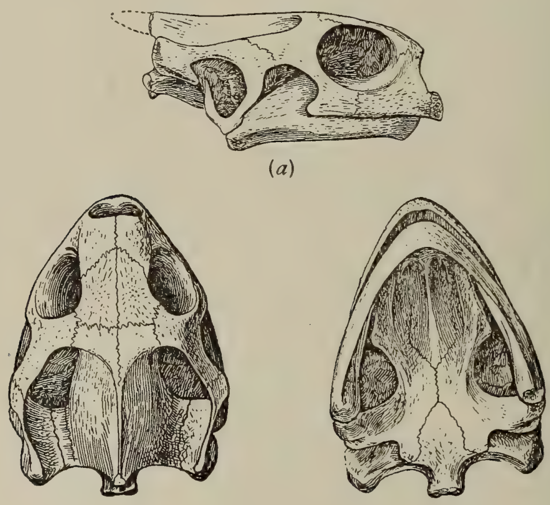
Upper Miocene.
- *Testudo ediae* Hay.
- *Testudo hollandi* Hay.
- *Testudo niobrarensis* Leidy.

Of all these only *Stylemys nebrascensis* occurs in abundance. So far as I have learned each of the others is known only by one or two specimens. Published reference to these latter is meagre and confined in the main to brief scientific description. For the purpose of this paper there seems little

*These large sized Tertiary forms should not be confused with the far larger Cretaceous turtles found in the black Pierre shales near the Big Badlands. These Cretaceous turtles became veritable monsters and reached a greater size than any others yet found anywhere in the world, either living or fossil. The type specimen, found near Railroad Buttes, southeast of the Black Hills and described by Mr. Wieland in 1896, had a total length of approximately eleven feet, and fragmentary portions of a still larger individual showed a length of forty inches for the head alone.

need to refer to them in further detail here but anyone wishing to continue their investigation will find an excellent help in Mr. O. P. Hay's great work, "The Fossil Turtles of North America." published in 1908 by the Carnegie Institute of Washington.

Stylemys nebrascensis, the common form, was first described in 1851, by Dr. Joseph Leidy, and is the earliest discovered fossil turtle in America (see Plate 50). The first specimens were obtained by Dr. John Evans of the Owen Geological Survey in 1849 and since then hundreds of specimens have found their way into the museums of the world. The visitor in the Badlands can scarcely fail to find them if he walks along the outcrops of the containing strata and in favorable localities he may see them with surprising frequency. I myself have observed many dozens of them in a few hours walk in Indian draw and there are other places where they seem to be as abundant. They are found particularly in the Oreodon beds but occur in the Protoceras beds also. As yet none have been found in the Titanotherium beds.



(*a*) (*b*) (*c*)

Figure 19—Head of *Stylemys nebrascensis.* Natural size. (a) view of right side. (b) view from above. (c) view from below. After Hay, 1906.

The shell body is often preserved with remarkable perfection but owing to the fact that weathering readily separates the bones, specimens exposed on the surface are usually more or less disintegrated. The head and feet are rarely found. Dr. Leidy,

who first described the species stated that he had seen hundreds of shells but no skull. Even today there is record of only two skulls. One of these in the Carnegie Museum of Pittsburg is accompanied by the shell (see Figure 19). The other is in the Princeton Museum but the body to which it belonged was not found. This general absence of the head is due perhaps to the fact that Stylemys was a dry land tortoise and any freshet that might be able to carry or roll the heavy decaying body into water where deposition was taking place would wrench the head away. This, separated from the body, would be inconspicuous and hence fail of ready detection.

Several fossil turtle eggs have been found in the Badlands and they are regarded as belonging to the common species just described. Hay states that they are slightly elongated but he indicates that this is perhaps due to deformation by pressure from an original globular form. They are a little less than two inches in diameter. They were formerly in the James Hall collection but are now in the American Museum of Natural History.

LIZARDS.

But few remains of lizards have been found within the badland formations. Cope in 1873 described *Aciprion formosum* from fragmentary material and in 1882 the Princeton expedition found a lower jaw of the same species. Dr. George Bauer briefly described two other species in the American Naturalist in 1893. These are *Rhineura hatcheri* and *Hyporhina antigua.* No figures were given. In 1901 Mr. O. A. Peterson of the Carnegie Museum found two nearly complete skulls of *Rhineura hatcheri* and a fragment of a third on Badland Creek, Sioux County, northwestern Nebraska. Mr. Earl Douglass described and figured the two better preserved skulls in 1908 in the Annals of the Carnegie Museum. The full length of the head is little more than one-half inch. An enlarged side view of one of these is given in Figure 20.

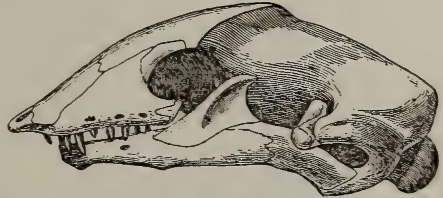


Figure 20—Head of *Rhineura hatcheri*, enlarged nearly four times. After Douglass, 1908.

CROCODILES

So far as I am aware only one species of crocodile from the badland formations of the Black Hills region has been described but fragments of several individuals have been found. Two localities not far beyond the boundaries of the region have furnished additional material. One of these, White Butte, North Dakota, about thirty-five miles northeast of Cave Hills, has afforded a tooth. This was discovered in 1905 by Mr. Earl Douglass of the Carnegie Museum, in beds of Oligocene age. The other locality is an indefinite one in the lower Niobrara valley (possibly not far from Fort Niobrara) where Prof. Marsh in 1873 found certain remains on which in 1877 he established the species Crocodilus salaris. He states that the beds in which the material was found are of Pliocene age. Present correlation would seem to indicate them to be Miocene.

In 1899 I found in the eastern breaks of Indian Creek valley about six miles northeast of Sheep Mountain, the anterior portion of the head of one individual. Prof. H. B. Loomis of Amherst College in 1903 found various fragments near the Cheyenne river. He also obtained in the Finney Breaks near Folsom a considerable number of bones and other remains. All of these came from the Titanotherium beds. Prof. Loomis described these specimens in the American Journal of Science, vol. 18, 1904, pp. 427-429, under the name *Crocodilus prenasalis* using the above mentioned imperfect head as the type of the species. The part of the head that is preserved is broad and short and contains the root portions of eighteen teeth, two of which retain the nearly complete crowns. These are conical and slightly recurved and the longest is approximately one-half inch in length. The position of the undivided individual nasal opening is far forward, hence the specific name prenasalis. The portion of the head preserved, the snout, shows a width of two and five eighths inches within two inches of the nasal end. The complete skeleton was evidently of considerable size although the full dimensions are conjectural.

BIRDS EGGS

Several fossil birds eggs have been found in or near the Big Badlands. Unlike eggs found elsewhere as fossils the Badland birds eggs are distinctly petrified, that is they show a practically complete replacement of the original matter by mineral material. Soft animal tissues quickly decay and only

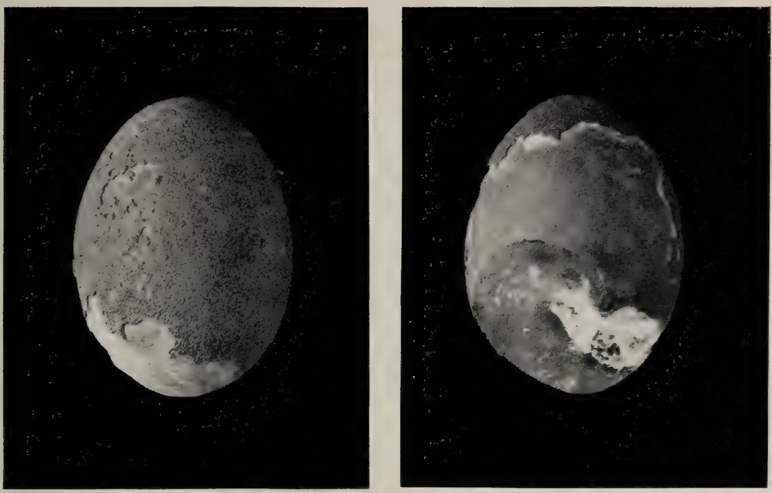


Figure 1. Petrified egg of a supposed anatine bird of Oligocene age. Farrington, 1899.

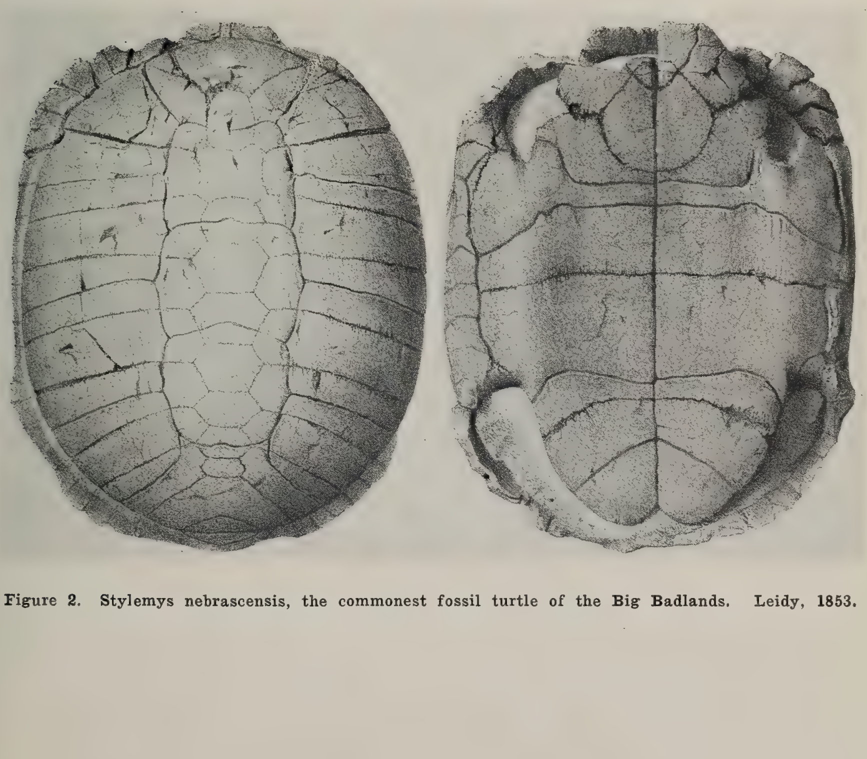


Figure 2. Stylemys nebrascensis, the commonest fossil turtle of the Big Badlands. Leidy, 1853.

exceptional conditions allow for their preservation or petrefaction. Turtle eggs are occasionally found filled with hardened mud and eggs of certain extinct birds have been preserved by reason of the thickness of their shells but the Badland birds eggs show not only the thickness of the original shell but also the position of the white and the yolk of the egg.

One of the Badland eggs found by Mr. Kelly Robinson in 1896 has been carefully described by Dr. O. C. Farrington of the Field Museum (see Plate 50). The shell portion is made up of dark colored chalcedony, the color being due to organic matter. The portion representing the white of the egg is gray translucent chalcedony with occasional black blotches the exact nature of which was not determined. The yolk is replaced by opal in two portions of about equal size but with different texture. The egg measures 2.03 inches by 1.49 inches, long and short diameters, conforming in size and general shape to that of the present day Florida duck (*Anas fulvigula*).*

Since the publication of the paper by Mr. Farrington I have seen another birds egg from our Badlands, perfect in outline and similar in size and shape to the one described. Others are reported to have been found.

In addition to the birds eggs several turtles eggs have been found. For a brief description of these the reader is referred to the subject of turtles in this paper.

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*Farrington, O. C. A Fossil Egg from South Dakota. Field Columb. Mus., Geol. Ser., Vol. 1 1899, pp. 193-200. 2 pls.

A List of the Fossil Mammals Found in the Badland Formations of the Black Hills Region.*

LOWER OLIGOCENE (TITANOTHERIUM ZONE.)

Carnivora (Fissipedia).
- Canidae.
  - Daphoenus dodgei Scott. Am. Phil. Soc., Trans., vol. 19, 1898, p. 362. Nw. Neb.
- Felidae.
  - Dinictis fortis Adams.

Perissodactyla.
- Rhinocerotidae.
  - Trigonias osborni Lucas. U. S. Nat. Mus., Proc., vol. 23, 1900, pp. 221-223. So. Dak.
  - Leptacerathe-ium trigonodum Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, pp. 201-203, (Aceratherium). So. Dak.
  - Caenopus cf. platycephalus Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, p. 206, (Aceratherium). So. Dak.
  - Caenopus mitis Cope.
- Lophiodontidae.
  - Colodon (Mesotapirus) occidentalis Leidy.
- Equidae.
  - Mesohippus proteulophus Osborn.
  - Mesohippus hypostylus.
  - Mesohippus celer Marsh. Am. Jour. Sci., vol. 7, 1874, p. 251, (Anchitherium). Nw. Neb.
- Titanotheriidae (Brontotheriidae).
  - Titanotherium prouti Leidy.
  - Titanotherium helocerus (Cope).
  - Titanotherium trigonoceras (Cope).
  - Megacerops dispar (Marsh). Am. Jour. Sci., vol. 34, 1887, p. 328, (Brontops). So. Dak.

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*A few fossil forms too poorly preserved to admit of careful description and naming have been omitted from this list. In compiling the list I have made extensive use of Matthew's Faunal Lists of the Tertiary Mammalia of the West as given in U. S. Geological Survey Bulletin No. 361, 1909. I have made no effort on my own part to indicate the relative value of synonyms where synonyms exist, but have endeavored to follow closely the nomenclature as given by Matthew. For additional convenient helpful literature the reader is referred to Hay's Bibliography and Catalogue of the Fossil Vertebrata of North America, U. S. Geological Survey Bulletin No. 179, 1902, and to Palmer's Index Generum Mammalium; a List of the Genera and Families of Mammals, U. S. Department of Agriculture, Division of Biological Survey, 1904.

Effort has been made to indicate the scientific paper in which each form was first described and named, its year of publication, also the approximate locality within the area covered by the accompanying map of the Black Hills region where the earliest or type specimen was found. Such reference is omitted in a few instances where I have not had opportunity to examine the original publication. So. Dak. means in all case the southwestern part of the state. Mauv. Terres where used corresponds fairly well to the Big Badlands, hence refers generally to fossils from South Dakota.

Soricidae.

Protosorex crassus Scott. Acad. Nat. Sci., Phila., Proc., 1894, pp. 446-448, So. Dak.

Bottom of p. 126.

Megacerops tichoceras Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 159-160, (Menodus) So. Dak.

Megacerops robustus (Marsh). Am. Jour. Sci., vol. 34, 1887, pp. 326-327, (Brontops). Nw. Neb.

Megacerops brachycephalus Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, pp. 97-98. So. Dak.?

Megacerops bicornutus Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, p. 99. So. Dak.?

Megacerops marshi Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, pp. 100-101. So. Dak.?

Allops serotinus Marsh. Am. Jour. Sci., vol. 34, 1887, p. 331. So. Dak.

Allops crassicornis Marsh. Am. Jour. Sci., vol. 42, 1891, pp. 268-269. So. Dak.

Allops amplus (Marsh). Am. Jour. Sci., vol. 39, 1890, pp. 523-524, (Diploclonus). So. Dak.

Symborodon montanus (Marsh). Am. Jour. Sci., vol. 9, 1875, p. 246, (Anisacodon). Nw. Neb.

Symborodon copei Osborn, Am. Mus. Nat. Hist., vol. 24, 1908, pp. 616-617. So. Dak.

Brontotherium ramosum (Osborn).

Brontotherium dolichoceras (Scott and Osborn). Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 160-161, (Menodus). So. Dak.

Brontotherium leidyi Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, pp. 105-106. So. Dak.

Brontotherium hatcheri Osborn. Am. Mus. Nat. Hist., Bull., vol. 24, 1908, pp. 615-616. So. Dak.

Artiodactyla.

Elotheriidae (Entelodontidae).

Elotherium (Entelodon) crassum Marsh. Am. Jour. Sci., vol. 5, 1873, pp. 487-488.

Anthracotheriidae.

Hyopotamus (Ancodon) americanus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 59. So. Dak.

Oreodontidae (Agriochoeridae).

Oreodon (Merycoidodon) hybridus Leidy. Ext. Mam. of Dak. and Neb., 1869, pp. 105-106. Mauv. Terres.

Oreodon (Merycoidodon) affinis Leidy. Ext. Mam. of Dak. and Neb., 1869, p. 105. Mauv. Terres.

Oreodon (Merycoidodon) bullatus Leidy. Ext. Mam. of Dak. and Neb., 1869, p. 106. Mauv. Terres.

Hypertragulidae.

Heteromeryx dispar Matthew.

MIDDLE OLIGOCENE (OREODON ZONE.)

Carnivora (Creodonta).

Hyaenodontidae.

Hyaenodon horridus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, pp. 392-393. Mauv. Terres.

Hyaenodon cruentus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, p. 393. Mauv. Terres.

Hyaenodon crucians Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, p. 393. Mauv. Terres.

Hyaenodon paucidens Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, pp. 223-224. So. Dak.

Hyaenodon leptocephalus Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, p. 152.

Hyaenodon mustelinus Scott, Acad. Nat Sci., Phila., Jour., vol. 9, 1894, pp. 499-500, So. Dak.

Carnivora (Fissipedia).

Canidae.

Daphoenus vetus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, p. 393, Mauv. Terres.

Daphoenus hartshornianus (Cope).

Daphoenus felinus Scott. Am. Philos. Soc., Trans., vol. 19, 1898, pp. 361-362, Nw. Neb.

Daphoenus nebrascensis (Hatcher), Carnegie Mus., Mem., vol. 1, 1902, pp. 95-99, (Proamphicyon). Nw. Neb.

Daphoenus inflatus (Hatcher), Carnegie Mus., Mem., vol. 1, 1902, pp. 99-104, (Protemnocyon). Nw. Neb.

Cynodictis gregarius (Cope).

Cynodictis lippincottianus (Cope).

Felidae.

Dinictis felina Leidy, Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 91, Mauv. Terres.

Dinictis squalidens (Cope).

Dinictis paucidens Riggs.

Hoplophoneus primaevus (Leidy).

Hoplophoneus occidentalis (Leidy), Acad. Nat. Sci., Phila., Jour., vol. 7, 1869, pp. 63-64, (Depranodon). Mauv. Terres.

Hoplophoneus oreodontis Cope.

Insectivora.

Erinaceidae.

Proterix loomisi Matthew.

Leptictidae.

Leptictis haydeni Leidy.

Ictops dakotensis Leidy.

Ictops bullatus Matthew. Am. Mus. Nat. Hist., Bull., vol. 12, 1899, p. 55, So. Dak.

Ictops porcinus (Leidy).

Rodentia.
 Castoridae.
  Eutypomys thomsoni Matthew.
 Ischyromyidae.
  Ischyromys typus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 89. Mauv. Terres.
 Muridae.
  Eumys elegans Leidy, Acad. Nat. Sci., Phila., Proc., vol 8, 1856, p. 90. Mauv. Terres.
 Leporidae.
  Palaeolagus haydeni Leidy, Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, pp. 89-90, Mauv. Terres.
  Palaeolagus turgidus Cope.

Perissodactyla.
 Hyracodontidae.
  Hyracodon nebrascensis Leidy.
  Hyracodon major Scott and Osborn, Mus. Comp. Zool., Bull., vol. 13, 1887, p. 170. So. Dak.?
 Amynodontidae.
  Metamynodon planifrons Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 165-169. So. Dak.

Rhinocerotidae.
  Caenopus (Subhyracodon) occidentalis Leidy.
  Caenopus (Subhyracodon) copei Osborn. Am. Mus. Nat. Hist., Mem., vol. 1, 1898, pp. 146-150, (Aceratherium). So. Dak.
  Caenopus (Subhyracodon) simplicidens Cope.
  Leptaceratherium trigonodum (Osborn and Wortman).
  "Hyracodon" planiceps Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 170-171, So. Dak.
 Lophiodontidae.
  Colodon (Mesotapirus) procuspidatus Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 7, 1895, pp. 362-364. So. Dak.
  Colodon (Mesotapirus) dakotensis Osborn and Wortman. Am. Mus. Nat Hist., Bull., vol. 7, 1895, pp. 362-364. So. Dak.
  Colodon (Mesotapirus) longipes Osborn and Wortman, Am. Mus. Nat. Hist., Bull., vol. 7, 1895, p. 366, So. Dak.
 Tapiridae.
  Protapirus simplex Wortman and Earle, Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 168-169. So. Dak.
 Equidae.
  Mesohippus bairdi Leidy.
  Mesohippus obliquideus Osborn, Am. Mus. Nat. Hist., Bull., vol. 20, 1904, p. 173. So. Dak.

Artiodactyla.
 Elotheriidae (Entelodontidae).
  Elotherium (Entelodon) mortoni Leidy.
  Elotherium (Entelodon) ingens Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, pp. 164-165. Mauv. Terres.

Dicotylidae (Tagassuidae).

Perchoerus probus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 165. Mauv. Terres.

Perchoerus nanus (Marsh). Am. Jour. Sci., vol. 48, 1894, p. 271, (Thinohyus). So. Dak.

Anthracotheriidae.

Anthracotherium curtum (Marsh). Am. Jour. Sci., vol. 47, 1894, p. 409, Heptacodon. So. Dak.

Hyopotamus (Ancodon) rostratus Scott. Acad. Nat. Sci., Phila., Jour., vol. 9, 1894, Appendix, p. 536. So. Dak.

Leptochoeridae.

Leptochoerus spectabilis Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 88. Mauv. Terres.

Leptochoerus gracilis Marsh. Am. Jour. Sci., vol. 48, 1894, pp. 271-273. So. Dak.

Stibarus quadricuspis (Hatcher). Carnegie Mus., Ann., vol. 1, 1901, pp. 131-134, (Leptochoerus).

Oreodontidae (Agriochoeridae).

Agriochoerus antiquus Leidy.

Agriochoerus latifrons Leidy. Ext. Mam. of Dak. and Neb., 1869, pp. 135-141. Mauv. Terres.

Oreodon (Merycoidodon) culbertsoni (Leidy).

Oreodon (Merycoidodon) gracilis Leidy.

Oreodon (Merycoidodon) sp. cf. bullatus Leidy.

Hypertragulidae.

Hypertragulus calcaratus Cope.

Leptomeryx evansi Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853. p. 394. Mauv. Terres.

Hypisodus minimus Cope.

Camelidae.

Poebrotherium wilsoni Leidy. Acad. Nat. Sci., Phila., Proc., vol. 3, 1847, pp. 322-326. Mauv. Terres.

Poebrotherium labiatum Cope.

Poebrotherium eximium Hay. U. S. Geol. Surv., Bull. No. 179, 1902, p. 67. This was first described by Wortman as Poebrotherium wilsoni Leidy. See Am. Mus. Nat. Hist., Bull., vol. 10, 1898, pp. 111-112. So. Dak.

Paratylopus primaevus Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 211-213. So. Dak.

UPPER OLIGOCENE.

(PROTOCERAS AND LOWER LEPTAUCHENIA ZONES.)

Carnivora (Fissipedia).

Canidae.

Cynodictis temnodon Wortman and Matthew. Am. Mus. Nat. Hist., Bull. ,vol. 12, 1899, p. 130.

Felidae.

Dinictis bombifrons Adams.

Hoplophoneus insolens Adams. Am. Jour. Sci., vol. 1, 1896, p. 429. So. Dak.

Eusmilus dakotensis Hatcher. Am. Nat., vol. 29, 1895, pp. 1091-1093. So. Dak.

Rodentia.

Castoridae.

Steneofiber nebrascensis (Leidy). Acad. Nat. Sci., Phila., Proc., vol. 8, p. 89. Mauv. Terres.

Perissodactyla.

Rhinocerotidae.

Caenopus tridactylus Osborn. Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 85-86, (Aceratherium). So. Dak.

Caenopus platycephalus Osborn and Wortman.

Tapiridae.

Protapirus obliquidens Wortman and Earle. Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 162-169. So. Dak.

Protapirus validus Hatcher. Am. Jour. Sci., vol. 1, 1896, pp. 162-168. So. Dak.

Equidae.

Mesohippus intermedius Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 7, 1895, pp. 334-356 So. Dak.

Mesohippus meteulophus Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 174-175. So. Dak.

Mesohippus brachystylus Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 175-176. So. Dak.

Miohippus validus Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, p. 177. So. Dak.

Miohippus gidleyi Osborn. Am. Mus. Nat. Hist., vol. 20, 1904, p. 178. So. Dak.

Miohippus crassicuspis Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 178-179. So. Dak.

Artiodactyla.

Elotheriidae (Entelodontidae).

Elotherium (Entelodon) cf. ingens Leidy.

Elotherium (Entelodon)? crassus Marsh.

Elotherium (Entelodon) bathrodon Marsh. Am. Jour. Sci., vol. 7, 1874, p. 534. So. Dak.

Dicotylidae (Tagassuidae).

Perchoerus robustus (Marsh). Am. Jour. Sci., vol. 48, 1894, p. 94, (Thinohyus).

Perchoerus platyops (Cope). Hayden Surv., Bull., vol. 6, pp. 174-175, (Palaeochoerus). So. Dak.

Anthracotheridae.

Anthracotherium karense Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, pp. 222-223. So. Dak.

Hyopotamus (Ancodon) brachyrhynchus Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, pp. 220-221. So. Dak.

Oreodontidae (Agriochoeridae).

Agriochoerus major Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 164. Mauv. Terres.

Agriochoerus gaudryi (Osborn and Wortman). Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 5-13, (Artionyx). So. Dak.

Agriochoerus migrans (Marsh). Am. Jour. Sci., vol. 48, 1894, pp. 270-271, (Agriomeryx). So. Dak.

Eporeodon (?Eucrotaphus) major (Leidy). Smithson. Contr.

to Knowl., vol. 6, p. 55, (Oreodon). So. Dak.
Eucrotaphus jacksoni Leidy.
Hypertragulidae.
Protoceras celer Marsh. Am. Jour. Sci., vol. 41, 1891, pp. 81-82. So. Dak.
Protoceras comptus Marsh. Am. Jour. Sci., vol. 48, 1894, pp. 93-94. So. Dak.
Protoceras nasutus Marsh.
Calops cristatus Marsh. Am. Jour. Sci., vol. 48, 1894, p. 94. So. Dak.
Calops consors Marsh.
Camelidae.
Pseudolabis dakotensis Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, p. 211. So. Dak.

LOWER MIOCENE.

Carnivora.
Canidae.
Nothocyon gregorii Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 183. So. Dak.
Nothocyon vulpinus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 183-184. So. Dak.
Nothocyon annectens Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 53-54. Nw. Neb.
Nothocyon? lemur Cope.
"Amphicyon" superbus Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 51-53, Nw. Neb.
Mesocyon robustus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 185. So. Dak.
Enhydrocyon crassidens Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 190-193. So. Dak.
Cynodesmus thomsoni Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 186-188. So. Dak.
Cynodesmus minor Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 189. So. Dak.
Mustelidae.
?Brachypsalis simplicidens Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 44-46. Nw. Neb.
Oligobunis lepidus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 194-195. So. Dak.
Megalictis ferox Matthew Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 197-204. So. Dak.
Aelurocyon brevifacies Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 68-72. Nw. Neb.
Felidae.
Nimravus sectator Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 204-205. So. Dak.
Insectivora.
Chrysochloridae.
Arctoryctes terrenus Matthew.
Rodentia.
Castoridae.
Euhapsis brachyceps Peterson. Carnegie Mus., Mem., vol.

2, 1905, pp. 179-184, (platyceps). Nw. Neb.

Euhapsis gaulodon Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 208-210. So. Dak.

Steneofiber? pansus Cope.

Steneofiber fossor Peterson. Carnegie Mus., Mem., vol. 2, 1905, pp. 140-166. Nw. Neb.

Steneofiber barbouri Peterson. Carnegie Mus. Mem., vol. 2, 1905, pp. 166-171. Nw. Neb.

Steneofiber simplicidens Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 205-207. So. Dak.

Steneofiber sciuroides Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 207. So. Dak.

Steneofiber brachyceps Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 208. So. Dak.

Geomyidae.

Entoptychus formosus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 212-213. So. Dak.

Entoptychus curtus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 213-214. So. Dak.

Leporidae.

Lepus primigenius Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 216. So. Dak.

Lepus macrocephalus Matthew. Am. Mus. Nat. Hist., vol. 23, 1907, pp. 214-216. So. Dak.

Proboscidea.

Gomphotherium conodon Cook. Am. Jour. Sci.,, vol. 28, 1909, pp. 183-184. Nw. Neb.

Perissodactyla.

Rhinocerotidae.

Diceratherium cooki Peterson. Science, vol. 24, 1906, pp. 282-283. Nw. Neb.

Diceratherium niobrarense Peterson. Science, vol. 24, 1906, pp. 281-282. Nw. Neb.

Chalicotheriidae.

Moropus? elatus Marsh. Am. Journ. Sci., vol. 14, 1877, pp. 250-251. So. Dak.

Equidae.

Parahippus aff. crenidens Scott.

Parahippus nebrascensis Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 57-60. Nw. Neb.

Parahippus tyleri Loomis. Am. Jour. Sci., vol. 26, 1908, pp. 163-164. Nw. Neb.

Artiodactyla.

Elotheriidae, (Entelodontidae).

Dinohyus hollandi Peterson. Science, vol. 22, 1905, pp. 211-212.

Dicotylidae (Tagassuidae).

Desmathyus siouxensis (Peterson). Carnegie Mus., Mem., vol. 2, 1906, pp. 308-320, (Thinohyus). Nw. Neb.

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*The nomenclature here given for the turtles is that of O. P. Hay in his recently published work, The Fossil Turtles of North America, 1908.

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